U.S. DEPARTMENT OF ENERGY | Office of Science

FY 2017 Budget Request to Congress for DOE's Office of Science

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science.energy.gov

Office of Science FY 2017 Budget Request to Congress

(Dollars in thousands)

	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Science						
Advanced Scientific Computing Research	541,000	523,411	621,000	663,180	+42,180	+6.8%
Basic Energy Sciences	1,733,200	1,682,924	1,849,000	1,936,730	+87,730	+4.7%
Biological and Environmental Research	592,000	572,618	609,000	661,920	+52,920	+8.7%
Fusion Energy Sciences	467,500	457,366	438,000	398,178	-39,822	-9.1%
High Energy Physics	766,000	745,232	795,000	817,997	+22,997	+2.9%
Nuclear Physics	595,500	580,744	617,100	635,658	+18,558	+3.0%
Workforce Development for Teachers and Scientists	19,500	19,500	19,500	20,925	+1,425	+7.3%
Science Laboratories Infrastructure	79,600	79,600	113,600	130,000	+16,400	+14.4%
Safeguards and Security	93,000	93,000	103,000	103,000	.....	.....
Program Direction	183,700	183,700	185,000	204,481	+19,481	+10.5%
University Grants (Mandatory)	.....	.....	.....	100,000	+100,000	.....
Small Business Innovation/Technology Transfer Research (SC)	.....	132,905	.....	.....	.....	.....
Subtotal, Science	5,071,000	5,071,000	5,350,200	5,672,069	+321,869	+6.0%
Small Business Innovation/Technology Transfer Research (DOE)	.....	65,075	.....	.....	.....	.....
Rescission of Prior Year Balance	-3,262	-3,262	-3,200	.....	+3,200	-100.0%
Total, Science	**5,067,738**	**5,132,813**	**5,347,000**	**5,672,069**	**+325,069**	**+6.1%**

Priorities for FY 2017

- **Maintain strong support for discovery science and world-class science facilities**
  - **Maintain a healthy balance among PI research, groups and centers, and facility operations**
  - **Continue to use community priorities to make difficult choices and design, build, operate, and sunset world-class facilities**
  - **Lead and steward the US accelerator science R&D capabilities**
  - **Lead and steward the US computational R&D capabilities, in collaboration with NNSA – garner support for and execute the exascale initiative**
  - **Support partnerships and collaborations**
- **Be proactive in supporting science for clean energy**
  - **Basic research needs workshops – partner with DOE technology offices and industry**
  - **Science-based transformational energy technology in Mission Innovation**
- **Increase relationship building with Congress**
- **Increase relationship building with research universities**
- **Given the importance of the DOE national labs in US R&D, institutionalize best practices in national lab management**

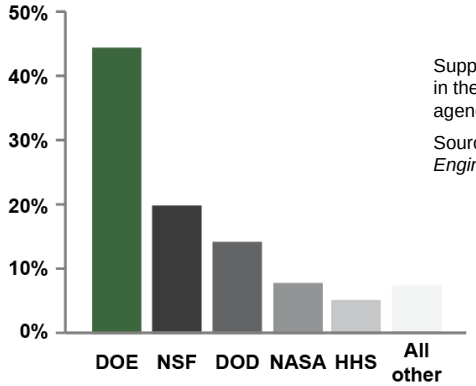
Office of Science
By the numbers

Shown is a portion of SLAC's two-mile-long linear accelerator (or linac), which provides the electron beam for the new Linac Coherent Light Source (LCLS) – the world's first hard x-ray, free-electron laser. For nearly 50 years, SLAC's linac had produced high-energy electrons for physics experiments. Now researchers use the very intense X-ray pulses (more than a billion times brighter than the most powerful existing sources) much like a high-speed camera to take stop-motion pictures of atoms and molecules in motion, examining fundamental processes on femtosecond timescales.

SC delivers scientific discoveries and tools to transform our understanding of nature and advance the energy, economic, and national security of the U.S.

Research

- Support for about half of the U.S. Federal support of basic research in the physical sciences;
- More than 20,000 Ph.D. scientists, grad students, engineers, and support staff at >300 institutions, including all 17 DOE labs;
- U.S. and world leadership in high-performance computing and computational sciences;
- Major U.S. supporter of physics, chemistry, materials sciences, and biology for discovery and for energy sciences.



Support for basic research in the physical sciences by agency.

Source: *NSF Science and Engineering Indicators 2012*

Scientific User Facilities

- The world's largest collection of scientific user facilities (aka research infrastructure) operated by a single organization in the world, used by more than 30,000 researchers each year.

SC Investments for Mission Innovation

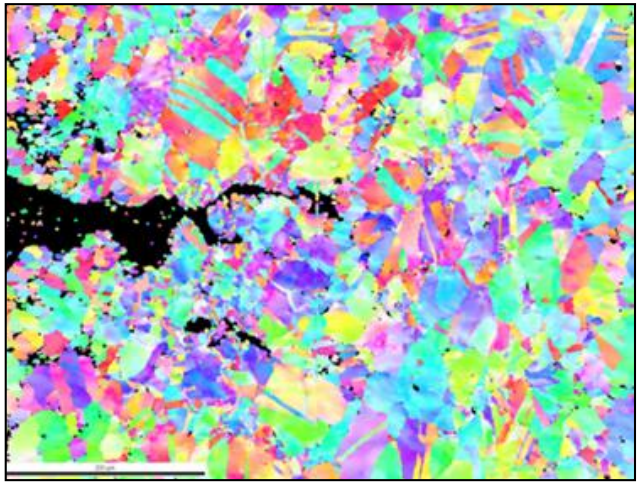
$100M in new funding in FY 2017

ASCR (+$10M)

- Computational Partnerships with EFRCs on solar, CO_2 reduction, catalysis, storage, subsurface, and biofuels; possibly new partnerships in wind and nuclear ($10M)

BES (+$51M)

- Energy Efficiency: Catalysts, modeled after nature's enzymes, that can operate at low-temperature and under ambient conditions; lightweight metallic materials; thermocaloric materials ($34.4M)
- Materials for Clean Energy: Self-healing materials for corrosive and high radiation environments (next-gen corrosive-resistant materials based on experiments and multi-scale modeling; chemistry under harsh or extreme environments) ($16.6M)



Analysis of cracks at the nanoscale

BER (+$35M)

- Biosystems design (computationally design and then bio-engineer biosystems) to introduce beneficial traits into plants and microbes for clean energy applications ($20M)
- Bioenergy Research Centers: New investments to translate 10 years of BRC research to industry ($15M, $5M per BRC)

FES (+4M)

- Whole-device fusion modeling and simulation using SciDAC partnerships ($4M)

SC Increases Academic Research by $100M (Mandatory) in FY 2017

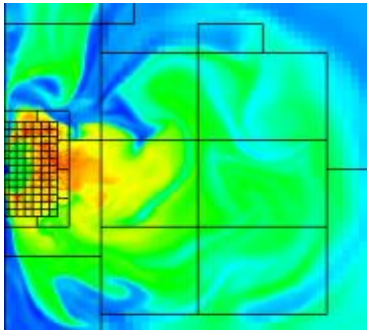
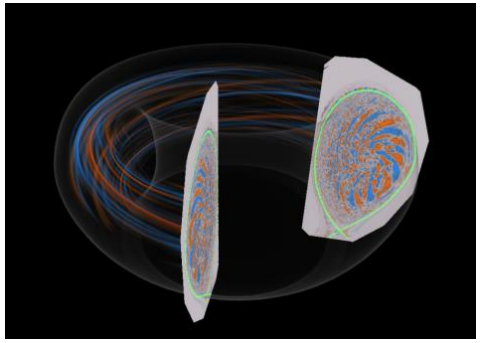
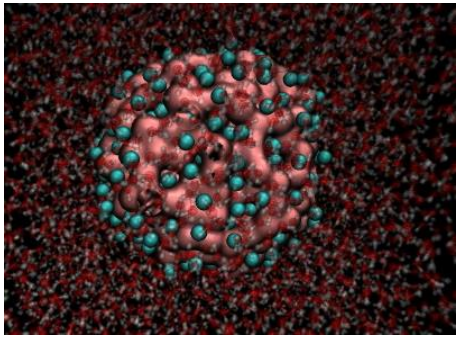
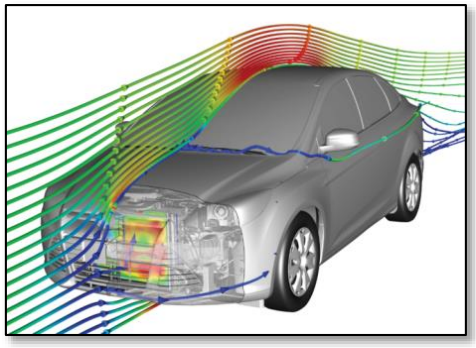
Investments are made in all of the SC programs, emphasizing emerging research areas, especially those recently identified by Federal Advisory Committees or other community activities. A few examples are:

- **ASCR**: Applications software, applied mathematics, and computer science for capable exascale computing; mathematics for large-scale scientific data; neuromorphic computing architectures and information processing for extreme and self-reconfigurable computing architectures
- **BES**: Topics described in the 2015 BESAC Report *Challenges at the Frontiers of Matter and Energy: Transformative Opportunities for Discovery Science*, including hierarchical architectures, non-equilibrium matter, non-ideal systems, coherence in light and matter, modeling & computation, and imaging across multiple scales.
- **BER**: New platform microbes for biofuels and bioproducts engineering; biofuel crop modeling for incorporation into a predictive framework.
- **FES**: Plasma/fusion research centers emphasizing the results of the 2015 community workshops, including for example low-temperature plasmas, plasma measurements, and verification & validation for magnetic fusion.
- **HEP**: Topics described in the 2014 HEPAP Long Range Plan and also topics that span multiple SC programs, including quantum information sciences/the entanglement frontier and quantum field theory across disciplines.
- **NP**: Topics described in the 2015 NSAC Long Range Plan, including research to accelerate discovery at FRIB, fundamental nuclear structure and nuclear astrophysics, fundamental symmetries, and super-heavy elements.

Advanced Scientific Computing Research

Computational and networking capabilities to extend the frontiers of science and technology

- **Exascale Computing Initiative (ECI) and Exascale Computing Project (ECP).** The ECP is initiated as a joint ASCR/NNSA partnership using DOE's formal project management processes. A new budget line is created for the ECP.
- **Facilities** operate optimally and with >90% availability; deployment of 10-40 petaflop upgrade at NERSC and site preparations for NERSC-9; upgrade of high traffic links on Esnet; and continued preparations for 180-200 petaflop upgrades at ALCF and OLCF.
- **SciDAC partnerships** will be recompeted in FY 2017 with new activities to include accelerating the development of clean energy technologies.
- **Applied Mathematics research** addresses challenges of increasing complexity and **Computer Science research** addresses exploration of "beyond Moore's law" architectures and supports data management, analysis, and visualization techniques.
- The **Computational Sciences Graduate Fellowship** is funded at $10,000K.

ASCR FY 2017 Budget Request to Congress

(Dollars in thousands)

	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Mathematical, Computational, and Computer Sciences Research						
Applied Mathematics	49,155	49,454	49,229	39,229	-10,000	-20.3%
Exascale	*(5,000)*	*(5,000)*	*(10,000)*	*(...)*	*(-10,000)*	*(-100.0%)*
Computer Science	55,767	55,259	56,848	39,296	-17,552	-30.9%
Exascale	*(20,000)*	*(20,000)*	*(20,423)*	*(...)*	*(-20,423)*	*(-100.0%)*
Computational Partnerships (SciDAC)	46,918	43,996	47,918	45,596	-2,322	-4.8%
Exascale	*(16,000)*	*(16,000)*	*(16,000)*	*(...)*	*(-16,000)*	*(-100.0%)*
Next Generation Networking for Science	19,000	19,011	19,000	19,000	...	...
SBIR/STTR	5,830	...	6,181	7,733	+1,552	+25.1%
Total, Mathematical, Computational, and Computer Sciences Research	**176,670**	**167,720**	**179,176**	**150,854**	**-28,322**	**-15.8%**
High Performance Computing and Network Facilities						
High Performance Production Computing (NERSC)	75,605	75,905	86,000	92,145	+6,145	+7.1%
Leadership Computing Facilities						
Leadership Computing Facility at ANL (ALCF)	80,320	81,796	77,000	80,000	+3,000	+3.9%
Leadership Computing Facility at ORNL (OLCF)	104,317	108,902	104,317	107,000	+2,683	+2.6%
Total, Leadership Computing Facilities	184,637	190,698	181,317	187,000	+5,683	+3.1%
Research and Evaluation Prototypes	57,329	53,298	121,471	17,890	-103,581	-85.3%
Exascale	*(50,000)*	*(50,000)*	*(111,471)*	*(...)*	*(-111,471)*	*(-100.0%)*
CSGF	*(3,000)*	*(3,000)*	*(10,000)*	*(10,000)*	*(...)*	*(...)*
High Performance Network Facilities and Testbeds (ESnet)	35,000	35,790	38,000	45,000	+7,000	+18.4%
SBIR/STTR	11,759	...	15,036	16,291	+1,255	+8.3%
Total, High Performance Computing and Network Facilities	**364,330**	**355,691**	**441,824**	**358,326**	**-83,498**	**-18.9%**
Exascale Computing						
17-SC-20 Office of Science Exascale Computing Project (SC-ECP)	...	...	...	154,000	+154,000	...
Total, Advanced Scientific Computing Research	**541,000**	**523,411**	**621,000**	**663,180**	**+42,180**	**+6.8%**

Components of the Exascale Program

- Exascale Computing Initiative (ECI)
  - The ECI was initiated in FY 2016 to support research, development, and computer-system procurements to deliver an exascale (10^{18} ops/sec) computing capability by the mid-2020s.
  - It is a partnership between SC and NNSA, addressing science and national security missions.
  - The Exascale Crosscut includes primary investments by SC/ASCR and NNSA/ASC and software application developments in both SC (BES and BER) and NNSA.

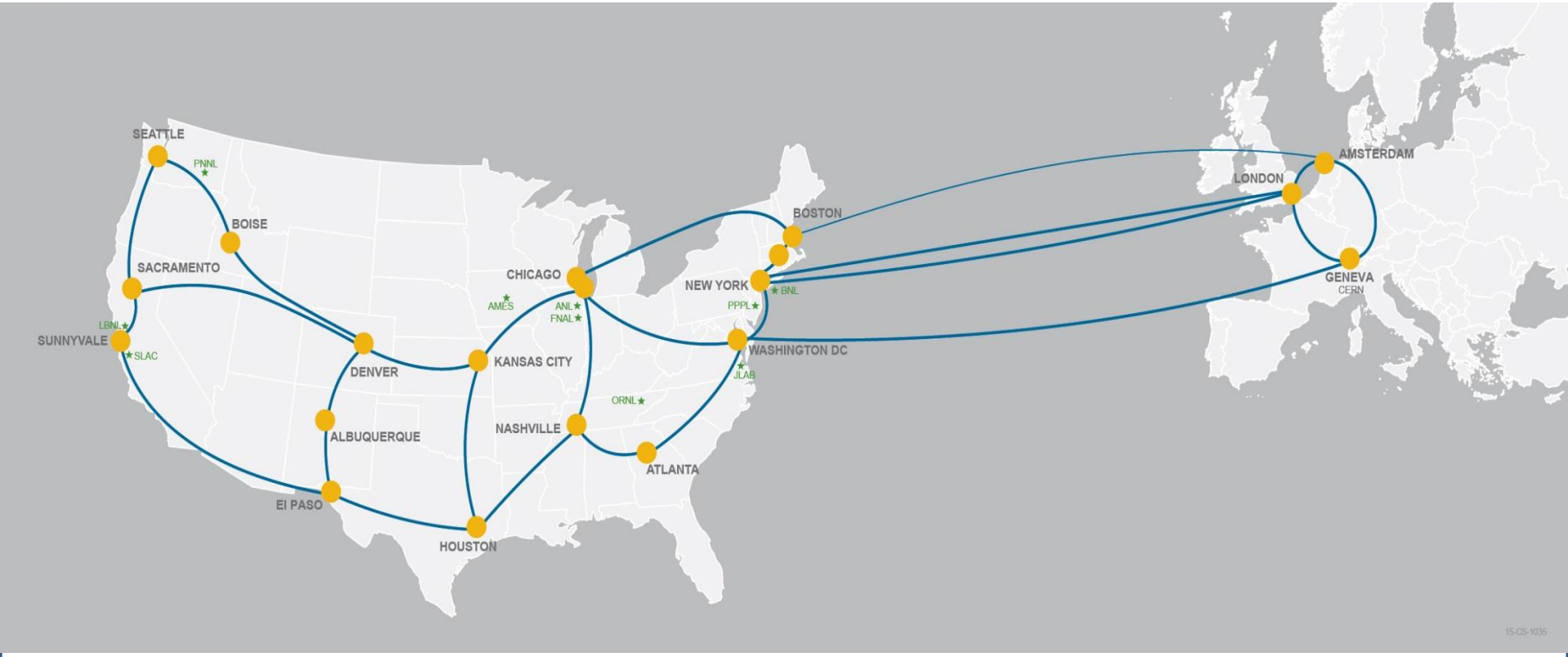
- Exascale Computing Project (ECP)
  - Beginning in FY 2017, the ASCR ECI funding is transitioned to the DOE project (the ECP), which is managed according to the principles of DOE Order 413.3b.
  - The new ECP subprogram in ASCR (SC-ECP) includes only activities required for the delivery of the exascale computers. An ECP Project Office has been established ORNL.
  - NNSA/ASC Advanced Technology Development and Mitigation (ATDM) supports activities for the delivery of exascale computers and the development of applications.

- Relationship of the ECI and ECP to the National Strategic Computing Initiative
  - On July 29, 2015, an executive order established the National Strategic Computing Initiative (NSCI) to ensure a coordinated Federal strategy in HPC research, development, and deployment.
  - DOE, along with the DoD and NSF, co-lead the NSCI. Within DOE, SC and NNSA execute the ECI and the ECP, which are the DOE contributions to the NSCI.

ASCR Computing Upgrades At a Glance

System attributes	NERSC Now	OLCF Now	ALCF Now	NERSC Upgrade	OLCF Upgrade	ALCF Upgrades	
Name Planned Installation	**Edison**	**TITAN**	**MIRA**	**Cori 2016**	**Summit 2017-2018**	**Theta 2016**	**Aurora 2018-2019**
System peak (PF)	2.6	27	10	> 30	200	>8.5	180
Peak Power (MW)	2	9	4.8	< 3.7	13.3	1.7	13
Total system memory	357 TB	710TB	768TB	~1 PB DDR4 + High Bandwidth Memory (HBM)+1.5PB persistent memory	> 2.4 PB DDR4 + HBM + 3.7 PB persistent memory	676 TB DDR4 + High Bandwidth Memory (HBM)	> 7 PB High Bandwidth On-Package Memory Local Memory and Persistent Memory
Node performance (TF)	0.460	1.452	0.204	> 3	> 40	> 3	> 17 times Mira
Node processors	Intel Ivy Bridge	AMD Opteron Nvidia Kepler	64-bit PowerPC A2	Intel Knights Landing many core CPUs Intel Haswell CPU in data partition	Multiple IBM Power9 CPUs & multiple Nvidia Voltas GPUS	Intel Knights Landing Xeon Phi many core CPUs	Knights Hill Xeon Phi many core CPUs
System size (nodes)	5,600 nodes	18,688 nodes	49,152	9,300 nodes 1,900 nodes in data partition	~4,600 nodes	>3,200 nodes	>50,000 nodes
System Interconnect	Aries	Gemini	5D Torus	Aries	Dual Rail EDR-IB	Aries	2nd Generation Intel Omni-Path Architecture
File System	7.6 PB 168 GB/s, Lustre®	32 PB 1 TB/s, Lustre®	26 PB 300 GB/s GPFS™	28 PB 744 GB/s Lustre®	120 PB 1 TB/s GPFS™	10PB, 210 GB/s Lustre initial	150 PB 1 TB/s Lustre®

ESnet Addresses Data Growth

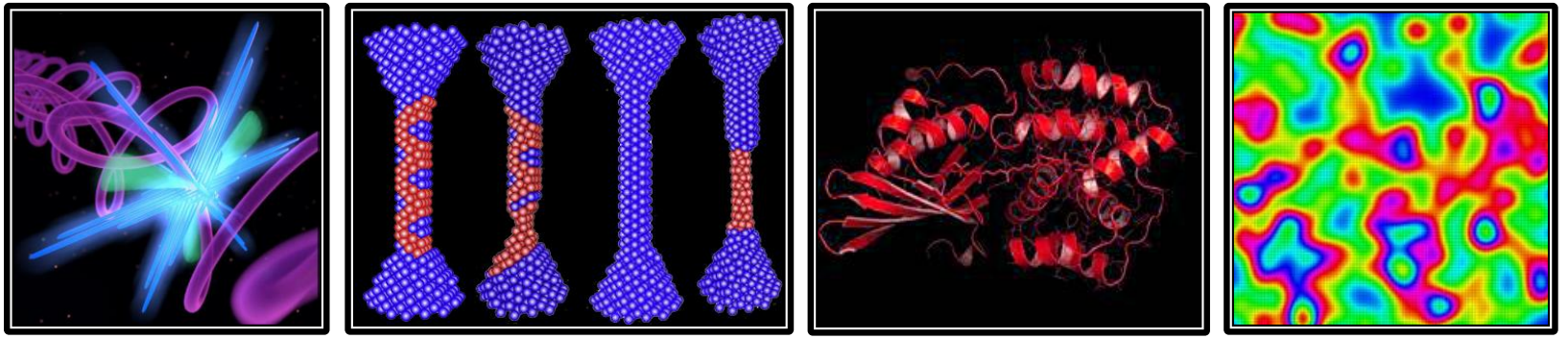


In FY 2017, the Energy Science Network (ESnet) will increase bandwidth to address the growing data requirements of SC facilities, such as the light sources, neutron sources, and particle accelerators at CERN. This includes upgrading high-traffic links to 400 gigabits per second (gbps). ESnet will also continue to extend science engagement efforts to solve the end-to-end network issues between DOE facilities and universities.

Basic Energy Sciences

Understanding, predicting, and controlling matter and energy at the electronic, atomic, and molecular levels

- Increased funding for **Energy Frontier Research Centers** (EFRCs) will fully fund up to five new awards in the area of subsurface science, with an emphasis on advanced imaging of geophysical and geochemical signals.
- A new activity in **Computational Chemical Sciences** will leverage U.S. leadership in computational chemistry community codes for petascale and in anticipation of exascale computing.
- Core research increases to advance the **Mission Innovation** agenda, targeting materials and chemistry for energy efficiency and for use in extreme environments.
- Both **Energy Innovation Hubs** continue. Joint Center for Energy Storage Research (JCESR) will be in its 5th year. Joint Center for Artificial Photosynthesis (JCAP) will be in its 3rd year of renewal.
- To maintain international competitiveness in discovery science, support continues for the **Linac Coherent Light Source-II (LCLS-II)** construction project and the **Advanced Photon Source Upgrade (APS-U)** major item of equipment project.
- BES **user facilities** operate at optimal levels.



BES FY 2017 Budget Request to Congress

(Dollars in thousands)

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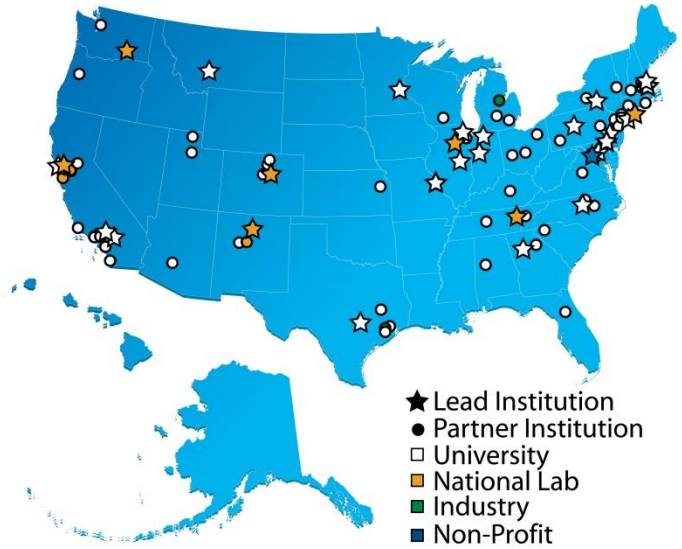
Materials Sciences and Engineering						
Research	258,951	259,209	250,319	280,989	+30,670	+12.3%
Experimental Program to Stimulate Competitive Research (EPSCoR)	9,951	9,951	14,776	8,520	-6,256	-42.3%
Energy Frontier Research Centers (EFRCs)	50,800	50,800	55,800	55,800	…	…
Energy Innovation Hubs—Batteries and Energy Storage	24,175	24,175	24,137	24,088	-49	-0.2%
Computational Materials Sciences	8,000	8,000	12,000	12,000	…	…
SBIR/STTR	12,008	…	12,758	14,448	+1,690	+13.2%
Total, Materials Sciences and Engineering	**363,885**	**352,135**	**369,790**	**395,845**	**+26,055**	**+7.0%**
Chemical Sciences, Geosciences, and Biosciences						
Research	239,086	238,164	231,129	256,853	+25,724	+11.1%
Energy Frontier Research Centers (EFRCs)	49,200	49,200	54,200	86,766	+32,566	+60.1%
Energy Innovation Hubs—Fuels from Sunlight	15,000	15,000	15,000	15,000	…	…
Computational Chemical Sciences	…	…	…	13,635	+13,635	…
General Plant Projects (GPP)	600	1,000	1,000	1,000	…	…
SBIR/STTR	10,350	…	10,732	14,102	+3,370	+31.4%
Total, Chemical Sciences, Geosciences, and Biosciences	**314,236**	**303,364**	**312,061**	**387,356**	**+75,295**	**+24.1%**
Scientific User Facilities						
Synchrotron Radiation Light Sources	447,186	450,103	481,906	489,059	+7,153	+1.5%
High-Flux Neutron Sources	244,113	245,050	264,645	261,177	-3,468	-1.3%
Nanoscale Science Research Centers	113,649	114,925	118,763	122,272	+3,509	+3.0%
Other Project Costs	9,300	9,300	…	…	…	…
Major Items of Equipment	42,500	42,500	35,500	20,000	-15,500	-43.7%
Research	31,713	26,847	34,853	37,537	+2,684	+7.7%
SBIR/STTR	27,918	…	31,182	33,484	+2,302	+7.4%
Total, Scientific User Facilities	**916,379**	**888,725**	**966,849**	**963,529**	**-3,320**	**-0.3%**
Subtotal, Basic Energy Sciences	**1,594,500**	**1,544,224**	**1,648,700**	**1,746,730**	**+98,030**	**+5.9%**
Construction						
13-SC-10 Linac Coherent Light Source-II (LCLS-II), SLAC	138,700	138,700	200,300	190,000	-10,300	-5.1%
Total, Basic Energy Sciences	**1,733,200**	**1,682,924**	**1,849,000**	**1,936,730**	**+87,730**	**+4.7%**

Energy Frontier Research Centers

FY 2016 = $110M; FY 2017 = $143M

Current EFRCs ($100M in FY 2015)

- 32 awards; $2-4M/year for 4 years (22 renewal, 10 new centers)
- Lead institutions by type: 23 universities; 8 DOE National Laboratories; 1 nonprofit organization
- Over 100 participating institutions, located in 33 states plus the District of Columbia



EFRCs 2009-14 ($100M/year+$277M ARRA)

- 46 EFRCs of $2-5M per year for 5 years

FY2016 Appropriation

- In 2016, there will be a Funding Opportunity Announcement (FOA) for up to five new EFRCs that focus on research directions under-represented in the current EFRC portfolio; included will be topics identified at the 2015 Basic Research Needs for Environmental Management Workshop.
- EFRC solicitations begin a two year FOA cycle.

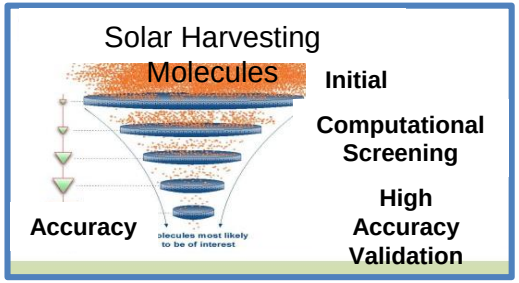
FY2017 Budget Request

- FY 2017 budget request includes an increase of $33M to fully fund up to 5 new EFRCs in subsurface science relevant to the Departmental Subsurface crosscut.
- The new EFRCs will support multidisciplinary teams to address the grand challenge identified in 2015 strategic planning activities: “Advanced imaging of geophysical and geochemical signals in the subsurface.”

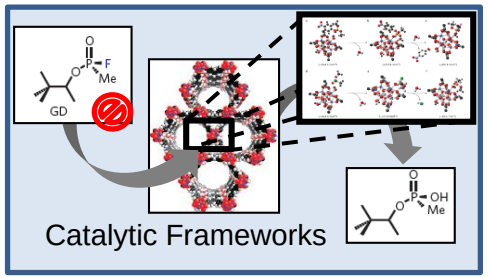
Computational Chemical Sciences
FY 2017 = $14M

Deliverable: Open-source modular chemistry codes and software packages that are automated, account for quantum/relativistic effects, and with sufficient accuracies for d- and f- electron systems

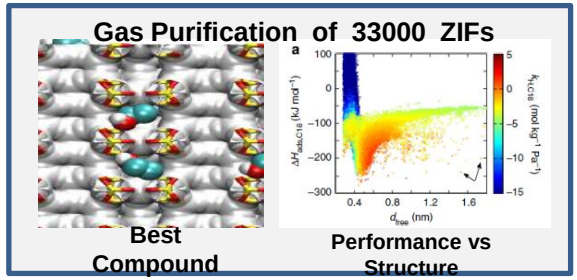
- A new activity -- $14M is requested to support 4-5 teams of researchers to capitalize on existing investments in quantum chemistry codes and upgrade them to be compatible with the current and future generations of high performance computers.
- Assemble teams of mathematical and computational chemists to develop open-source software with new algorithms to allow simulation of chemical processes of complex systems.
- Rewrite software and algorithms to fully realize the current and future gains in efficiency offered by massively parallel computing platforms.
- Deliver codes that treat electronic and spin effects in order to avoid case-by-case retooling of the model of electronic potential that is embedded in many current computational methods.



High-Accuracy Design of Catalysis



Artificial Photosynthesis

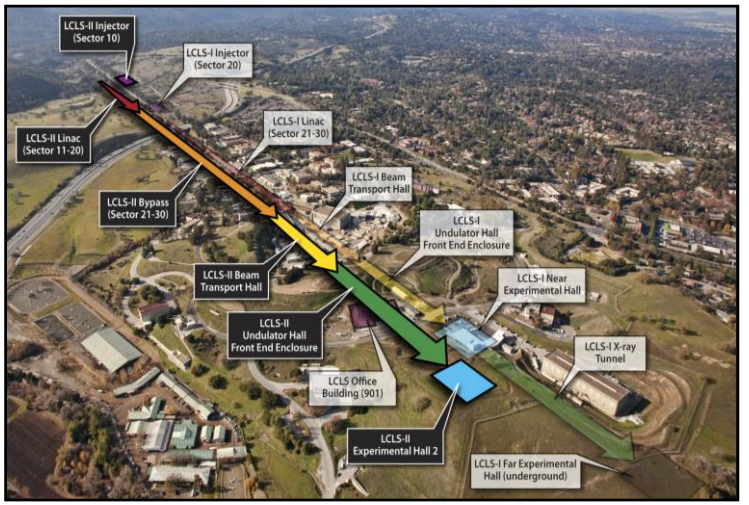


Field-Driven Chemical Rearrangements

LCLS-II and APS-U Underway

Linac Coherent Light Source-II (LCLS-II)

- FY 2016 = $200,300K; FY 2017 = $190,000K for R&D, design, prototyping, long lead procurement, and construction of technical systems.
- LCLS-II will provide high-rep-rate, ultra-bright, transform-limited femtosecond x-ray pulses with polarization control and pulse length control to ~1 femtosecond. The hard x-ray range will be expanded to 25 keV.
- Added are a 4 GeV superconducting linac; an electron injector; and two undulators to provide x-rays in the 0.2–5 keV energy range.



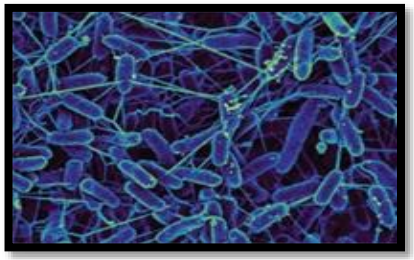
Advanced Photon Source Upgrade (APS-U)

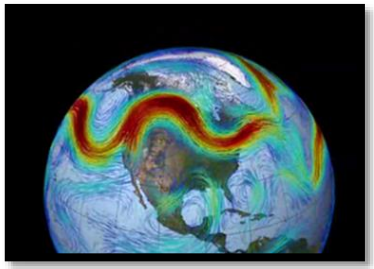
- FY 2016 = $20,000K; FY 2017 = $20,000K for R&D, design, and limited prototyping.
- APS-U will provide a multi-bend achromat lattice to provide extreme transverse coherence and brightness.
- Initial conceptual design for the new lattice completed; conducting R&D and key component prototyping in support of the new design. Key performance parameters are being defined for the project and the new storage ring.

Biological and Environmental Research

Understanding complex biological, climatic, and environmental systems

- **Genomic sciences** supports the Bioenergy Research Centers, new microbiome research, and increases efforts in biosystems design for bioenergy and renewable bioproducts.
- **Mesoscale-to-molecules** research supports the development of enabling technology to visualize key metabolic processes in plant and microbial cells at the subcellular and mesoscale.
- **Climate and Earth System Modeling** supports development of physical, chemical, and biological model components to simulate climate variability and change at regional and global scales.
- **Atmospheric System Research (ASR)** addresses major uncertainties in climate change models: the role of clouds and the effects of aerosols on precipitation, and the atmospheric radiation balance.
- **Environmental System Science** supports research to provide a robust, predictive understanding of terrestrial surface and subsurface ecosystems. Includes Next Generation Ecosystem Experiments targeting climatically sensitive terrestrial ecosystems not well represented in models.
- **Climate and Environmental Data Analysis and Visualization** employs server side analysis to simplify analysis of large scale observations with model-generated data.
- **User facilities operate at optimal levels: ARM** continues measurements at fixed sites, and mobile facilities deploy to the Arctic, Antarctic, and the Atlantic Ocean. **JGI** provides genome sequence data, synthesis, and analysis. **EMSL** continues novel research using the High Resolution and Mass Accuracy Capability.



BER FY 2017 Budget Request to Congress

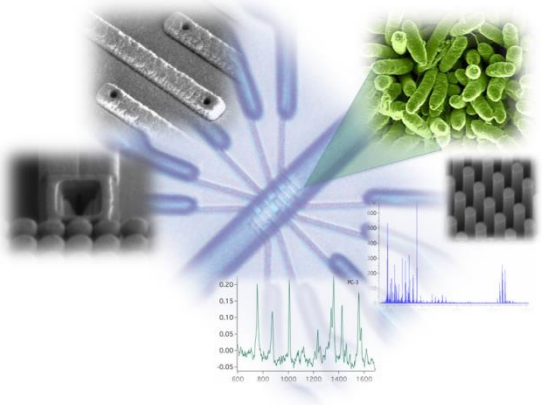
(Dollars in thousands)

	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Biological Systems Science						
Genomic Science						
Research	99,490	99,490	101,635	129,681	+28,046	+27.6%
Computational Biosciences	16,395	16,395	16,395	16,395	...	...
Bioenergy Research Centers	75,000	75,000	75,000	89,550	+14,550	+19.4%
Total, Genomic Science	190,885	190,885	193,030	235,626	+42,596	+22.1%
Mesoscale to Molecules	9,680	9,680	9,623	10,623	+1,000	+10.4%
Radiological Sciences	5,074	5,074	2,000	...	-2,000	-100.0%
Biological Systems Facilities and Infrastructure						
Structural Biology Infrastructure	14,895	14,895	10,000	10,000	...	...
Joint Genome Institute	69,500	69,500	69,500	70,463	+963	+1.4%
Total, Biological Systems Facilities and Infrastructure	84,395	84,395	79,500	80,463	+963	+1.2%
SBIR/STTR	9,858	...	10,118	12,339	+2,221	+22.0%
Total, Biological Systems Science	**299,892**	**290,034**	**294,271**	**339,051**	**+44,780**	**+15.2%**
Climate and Environmental Sciences						
Atmospheric System Research	25,892	25,966	26,392	26,392	...	...
Environmental System Science	67,567	67,567	63,242	63,242	...	...
Climate and Earth System Modeling	71,195	71,121	98,672	103,531	+4,859	+4.9%
Climate and Environmental Facilities and Infrastructure						
Atmospheric Radiation Measurement Climate Research Facility	67,429	67,429	65,429	65,429	...	...
Environmental Molecular Sciences Laboratory	45,501	45,501	43,191	45,552	+2,361	+5.5%
Data Management	5,000	5,000	7,066	7,066	...	...
Total, Climate and Environmental Facilities and Infrastructure	117,930	117,930	115,686	118,047	+2,361	+2.0%
SBIR/STTR	9,524	...	10,737	11,657	+920	+8.6%
Total, Climate and Environmental Sciences	**292,108**	**282,584**	**314,729**	**322,869**	**+8,140**	**+2.6%**
Total Biological and Environmental Research	**592,000**	**572,618**	**609,000**	**661,920**	**+52,920**	**+8.7%**

Biological Systems Science

Biological Systems Science supports basic research and technology development to achieve a predictive, systems-level understanding of complex biological systems.

Foundational knowledge in genome science with advanced computational and experimental approaches serves as the basis for the confident redesign of microbes and plants for sustainable biofuel and bioproducts production from renewable biomass and improved understanding of carbon/nutrient cycling and contaminant transport in the environment.



- Funding increases in Genomic Science support efforts in clean energy research including:
  - Increased efforts to speed bioenergy research results to commercial development.
  - Increased Biosystems Design efforts to underpin biotechnology advances for a bio-based economy.
  - New effort in Microbiome research for bioenergy.
- Increases in Mesoscale to Molecules will broaden the development of new bioimaging technology.

JGI JOINT GENOME INSTITUTE DEPARTMENT OF ENERGY

KBase PREDICTIVE BIOLOGY
DOE Systems Biology Knowledgebase

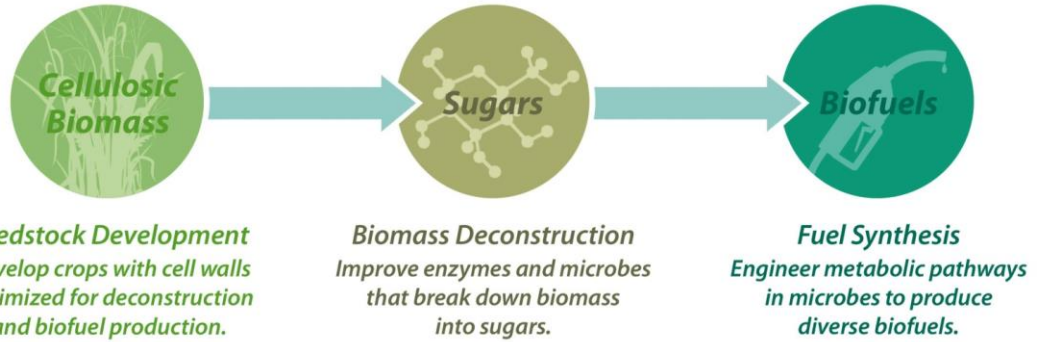
BESC BioEnergy Science Center

jbei Joint BioEnergy Institute

GREAT LAKES BIOENERGY RESEARCH CENTER

Bioenergy Research Centers—Innovation for Clean Energy

- **Established in 2007**
  - 795 invention disclosures/ patent applications
  - 32 patents awarded
  - 116 licensing agreements
  - 2108 peer-reviewed publications



- **Renewed for 5 years following merit review in September 2012. FY 2017 is the final year in the funded period.**

  BioEnergy Science Center (Oak Ridge National Lab)
  - Strategic focus on overcoming biomass "recalcitrance"
  - Goal of "Consolidated Bioprocessing" – one-microbe or microbial community approach going from plants to fuel

  Great Lakes Bioenergy Research Center (U. of Wisconsin, Michigan State U.)
  - Goal of re-engineering plants to produce more starches and oils
  - Using high throughput technologies to optimize chem/bio process for biomass deconstruction
  - Major research thrust on sustainability of biofuels

  Joint BioEnergy Institute (Lawrence Berkeley National Lab)
  - Experimenting with new pretreatment process using room temperature ionic liquids
  - Engineering *E.coli* and yeast to produce hydrocarbons, "green" gasoline, diesel, jet fuel

- **Increased funding accelerates innovation and translation of research results to industry ($5M for each BRC).**

- **A competitive FOA will be issued in FY 2016 for merit review and selection in FY 2017.**

Accelerated Climate Model for Energy (ACME)

ACME is a DOE multi-laboratory project to accelerate the assimilation of advanced software, numerical methods, and high resolution physics for the study of extreme phenomena

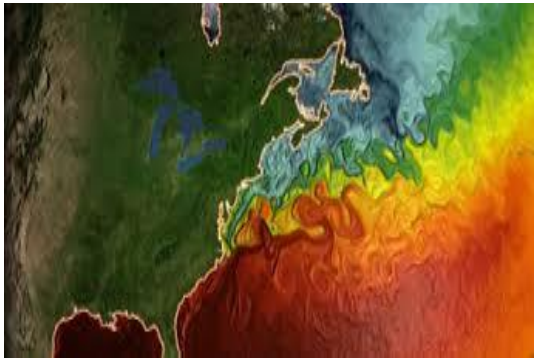
<u>World-leading capabilities</u>

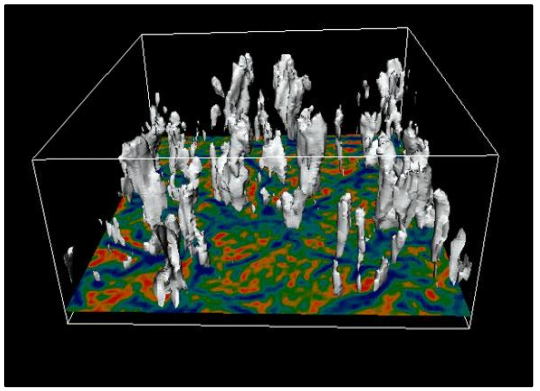
- Highest spatial resolution of all climate models in the world
  - Resolution at 15-25 km in fully coupled mode
  - Resolution below 10 km using advanced adaptive-mesh for specific regions
- Will be first climate model compatible with next generation computer architectures

<u>New science will be assimilated into ACME</u>

- Carbon cycle, with dynamic ecology, biogeochemistry, and land-atmosphere fluxes
- Detailed studies of the cryosphere: permafrost; ice sheets
- Detailed validation of ecosystem component models, using data from SC field projects in the Arctic and Tropics
- Uncertainty quantification for full system and its components

<u>Focus in FY 2017:</u> Testing with Large-Eddy-Simulation, based on high resolution details obtained from the Atmospheric Radiation Measurement Facility to better predict extremes.





Begun in 2014, involves 7 National laboratories and the National Center for Atmospheric Research (NCAR).

Pacific Northwest NATIONAL LABORATORY | OAK RIDGE National Laboratory | Argonne NATIONAL LABORATORY | Sandia National Laboratories | Los Alamos NATIONAL LABORATORY | BERKELEY LAB | BROOKHAVEN NATIONAL LABORATORY

FY 2017 SC Contributions to DOE Crosscuts

	Adv Mat	ECI	Sub-surface	EWN	Cyber-security	Total
Advanced Scientific Computing Res.	0	154,000	0	0	0	154,000
Basic Energy Sciences	17,600	26,000	41,300	0	0	84,900
Biological and Environmental Research	0	10,000	0	24,300	0	34,300
Safeguards and Security	0	0	0	0	27,197	27,197
Total, SC Contribution Crosscuts	17,600	190,000	41,300	24,300	27,197	300,397

Adv Mat: Advanced Materials Crosscut
ECI: Exascale Computing Initiative Crosscut
Subsurface: Subsurface Technology and Engineering RD&D Crosscut
EWN: Energy-Water Nexus Crosscut
Cybersecurity: Cybersecurity Crosscut

SC Contributes to Five FY 2017 DOE Crosscuts

Advanced Materials (Adv Mat): Identified as a priority in both the 2015 QTR and the QER, activities in the Adv Mat crosscut address faster development of new materials and reductions in the cost of materials qualification in clean energy applications, from discovery through deployment. New activities emphasize DOE-wide efforts in (1) materials design and synthesis, (2) applied design, (3) process scale-up, (4) qualification, and (5) digital data and informatics.

Exascale Computing Initiative (ECI): Activities in the ECI crosscut, a partnership between SC and NNSA, address accelerating R&D to overcome key challenges in parallelism, energy efficiency, and reliability, leading to deployment of exascale systems in the mid-2020s. In addition to underpinning DOE's missions in science and national security, the computational capabilities developed in the ECI also will support R&D in DOE's applied energy technology areas, as described in the 2015 QTR.

Subsurface Technology and Engineering RD&D (Subsurface): Activities in the Subsurface crosscut address coordinated research in Wellbore Integrity, Stress State and Induced Seismicity, Permeability Manipulation, New Subsurface Signals, and Risk Assessment Tools. Over 80 percent of our total energy supply comes from the subsurface; the goals of this crosscut are enhanced energy security, reduced impact on climate change via CO_2 sequestration, and significantly mitigated environmental impacts from energy-related activities and operations.

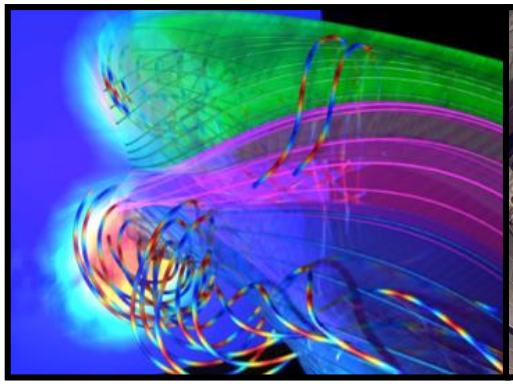
Energy-Water Nexus (EWN): The EWN crosscut addresses the transition to more resilient energy and coupled energy-water systems. The EWN crosscut supports: (1) an advanced, integrated data, modeling, and analysis platform to improve understanding and inform decision-making; (2) investments in targeted technology research offering the greatest potential for impact; and (3) policy analysis and stakeholder engagement designed to build from and strengthen the two preceding areas while motivating community involvement and response.

Cybersecurity: The Department of Energy (DOE) is engaged in two categories of cyber-related activities: protecting the DOE enterprise from a range of cyber threats that can adversely impact mission capabilities and improving cybersecurity in the electric power subsector and the oil and natural gas subsector. The cybersecurity crosscut supports central coordination of the strategic and operational aspects of cybersecurity and facilitates cooperative efforts such as the Joint Cybersecurity Coordination Center (JC3) for incident response and the implementation of Department-wide Identity Control and Access Management (ICAM).

Fusion Energy Sciences

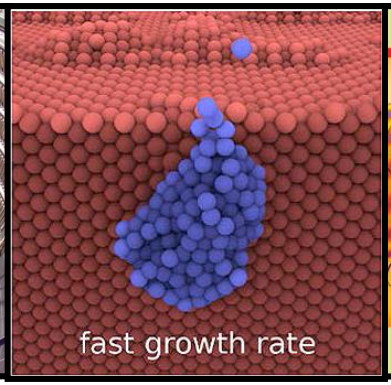
Matter at very high temperatures and densities and the scientific foundations for fusion

- Research is supported for the DIII-D and NSTX-U national programs.
- NSTX-U operates for 16 weeks; DIII-D operates for 14 weeks; Alcator C-Mod ceases operation as scheduled and MIT scientists collaborate full-time on domestic and international facilities.
- Support continues for U.S. research involvement on international machines EAST (China), KSTAR (Korea), and W7-X (Germany).
- HEDLP research is focused on the MEC instrument at LCLS.
- General plasma science activities continue, including the partnership with NSF for discovery-driven plasma science and engineering research.
- U.S. contributions to ITER support US ITER Project Office; the US direct contribution; and progress on hardware contributions, including fabrication of the central solenoid magnet modules and structures and the toroidal field magnet conductor.

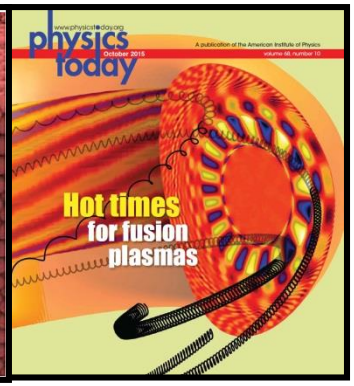


Magnetic reconnection driven by 3-D flux-rope interaction in the Large Plasma Device

New central solenoid magnet inside NSTX-Upgrade



Growth of helium bubbles that degrade tungsten performance



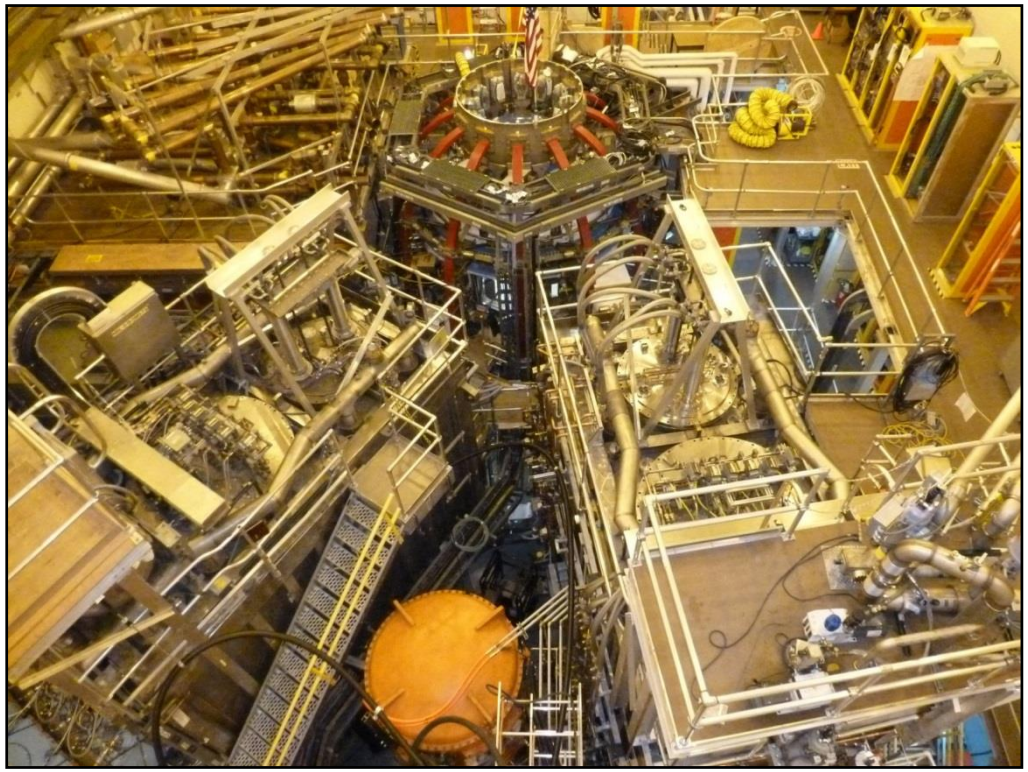
Gyrokinetic simulation of energetic ions in tokamak plasma

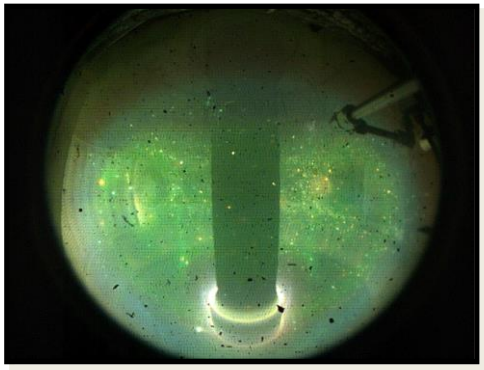
FES FY 2017 Budget Request to Congress

(Dollars in thousands)

	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Burning Plasma Science: Foundations						
Advanced Tokamak						
DIII-D	79,950	83,108	80,000	81,100	+1,100	+1.4%
Alcator C-Mod	22,260	21,429	18,000	...	-18,000	-100.0%
Enabling R&D	2,165	2,165	2,165	2,165	...	...
Small-scale Experimental Research	973	973	1,090	973	-117	-10.7%
Total, Advanced Tokamak	105,348	107,675	101,255	84,238	-17,017	-16.8%
Spherical Tokamak	72,919	71,169	74,000	73,199	-801	-1.1%
Theory & Simulation	34,670	35,006	33,500	33,170	-330	-1.0%
GPE, GPP, and Infrastructure	3,125	3,600	6,000	5,000	-1,000	-16.7%
Total, Burning Plasma Science: Foundations	**216,062**	**217,450**	**214,755**	**195,607**	**-19,148**	**-8.9%**
Burning Plasma Science: Long Pulse						
Long Pulse: Tokamak	7,695	7,895	8,500	6,045	-2,455	-28.9%
Long Pulse: Stellarators	6,419	8,010	7,269	5,084	-2,185	-30.1%
Materials & Fusion Nuclear Science	24,842	23,033	25,252	20,226	-5,026	-19.9%
Total, Burning Plasma Science: Long Pulse	**38,956**	**38,938**	**41,021**	**31,355**	**-9,666**	**-23.6%**
Discovery Plasma Science						
Plasma Science Frontiers						
General Plasma Science	15,800	15,469	16,125	15,500	-625	-3.9%
High Energy Density Laboratory Plasmas	19,815	19,165	20,250	7,000	-13,250	-65.4%
Exploratory Magnetized Plasma	10,409	10,009	10,409	9,416	-993	-9.5%
Total, Plasma Science Frontiers	46,024	44,643	46,784	31,916	-14,868	-31.8%
Measurement Innovation	3,575	3,575	6,700	4,000	-2,700	-40.3%
SBIR/STTR and Other	12,883	2,760	13,740	10,300	-3,440	-25.0%
Total, Discovery Plasma Science	**62,482**	**50,978**	**67,224**	**46,216**	**-21,008**	**-31.3%**
Subtotal, Fusion Energy Sciences	**317,500**	**307,366**	**323,000**	**273,178**	**-49,822**	**-15.4%**
Construction						
14-SC-60 International Thermonuclear Experimental Reactor (ITER)	150,000	150,000	115,000	125,000	+10,000	+8.7%
Total, Fusion Energy Sciences	**467,500**	**457,366**	**438,000**	**398,178**	**-39,822**	**-9.1%**

The NSTX Upgrade at PPPL is Complete





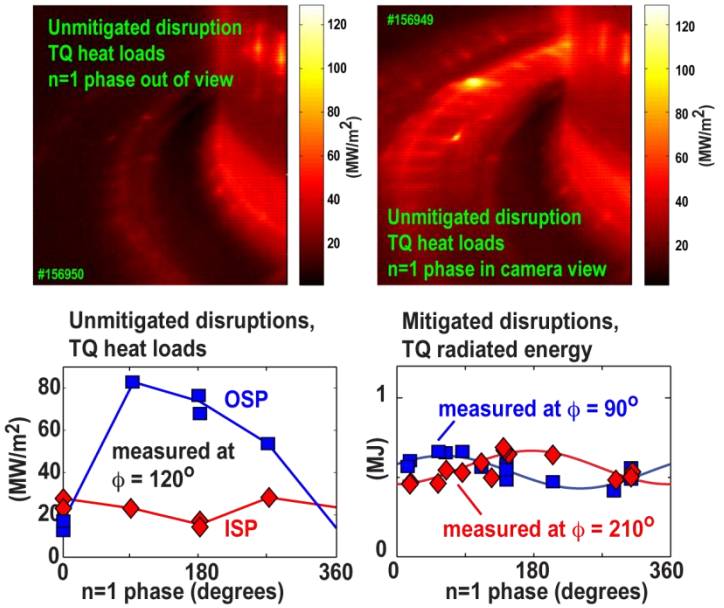
First plasma in NSTX-U achieved September 2015

- After the multi-year upgrade construction project completed in FY 2015, NSTX-U is world's highest-performance spherical tokamak.
- Funding will allow 16 weeks of run time in FY 2017.

- In mid-FY 2016, a shutdown is planned for installation of a row of high-Z metal tiles on the lower divertor shelf for experiments on plasma-wall interaction.
- In FY 2017, plasma performance, divertor heat flux mitigation, and non-inductive discharge sustainment will be tested at the full field and current values (both double what had been achieved prior to the upgrade).

DIII-D and its Upgrades at General Atomics

Interior of DIII-D vacuum vessel



DIII-D infrared camera data used to investigate asymmetries in tokamak disruptions

- DIII-D will continue high-priority advanced tokamak studies of transport, edge and divertor physics, disruption physics and tokamak transient mitigation systems. Research priorities will include issues identified by the 2015 community research needs workshops.
- After 14 run weeks, DIII-D will have a planned outage for the installation of targeted facility enhancements, including a new high-power helicon current drive antenna and improvements to the neutral beam injection systems for plasma heating and current drive.

U.S. Collaborations on International Superconducting Facilities

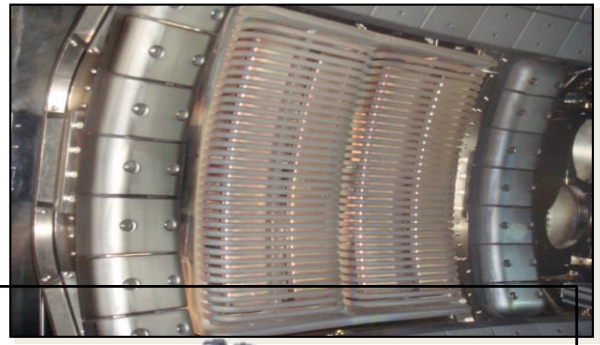
Experimental Advanced Superconducting Tokamak (EAST) – China

- U.S. scientists conducted experiments at a distance on EAST by operating the machine from a remote collaboration room at General Atomics—the first successful demonstration of "3rd shift" remote operation of this experiment.

General Atomics remote collaboration room supports 3rd shift operation of EAST by U.S. scientists

Korea Superconducting Tokamak Advanced Research (KSTAR) – Korea

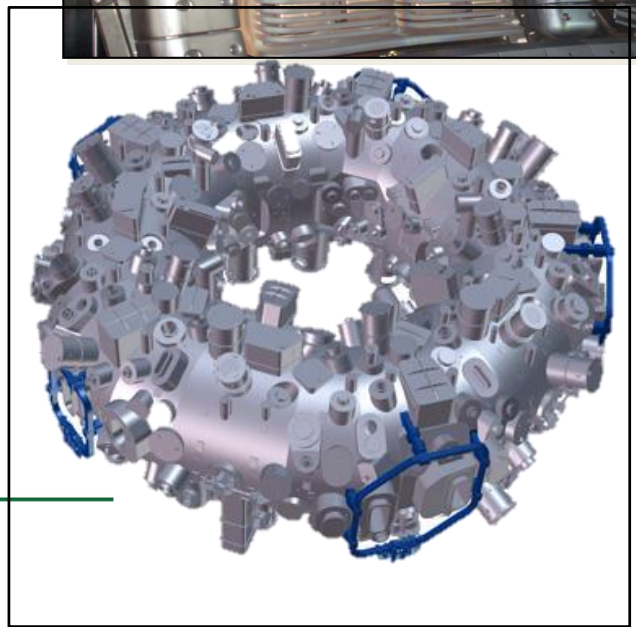
- U.S. contributions have improved the performance of the ion-cyclotron radio frequency antenna on KSTAR



U.S.-designed RF wave antenna to heat ions in KSTAR

Wendelstein W-7X Stellarator – Germany

- U.S. designed and constructed trim coils that fine-tune the shape of the plasma
- W-7X achieved first plasma in December 2015 with substantial U.S. involvement

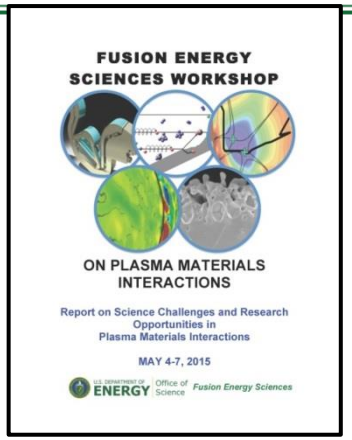


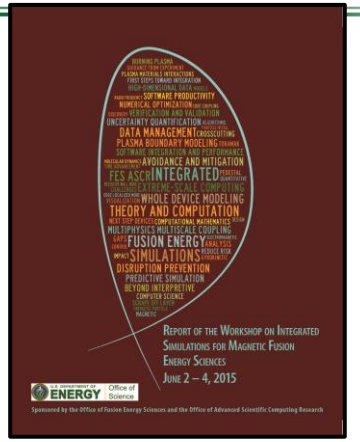
Five 2,400-pound U.S.-built trim coils (blue) installed on W7-X

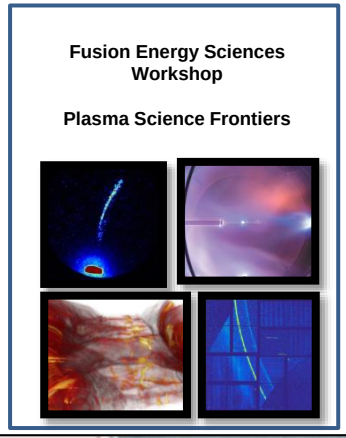
Community Engagement Workshops

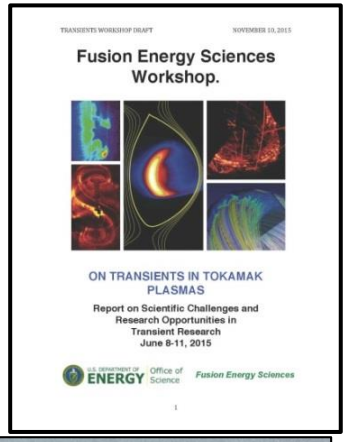
- Following the FESAC *Strategic Planning and Priorities Report* (2014), FES undertook a series of four technical workshops in 2015:
  - Workshop on Integrated Simulations for Magnetic Fusion Energy Sciences
  - Workshop on Transients
  - Workshop on Plasma Science Frontiers
  - Workshop on Plasma-Materials Interaction

- Each workshop is delivering a report that addresses scientific challenges and potential implementation options.

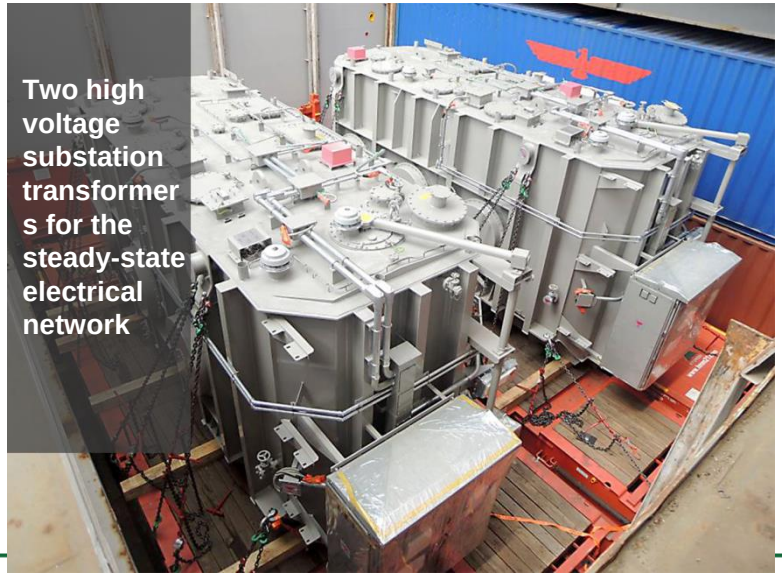








U.S. Fabrication of ITER Hardware Progressing



High Energy Physics

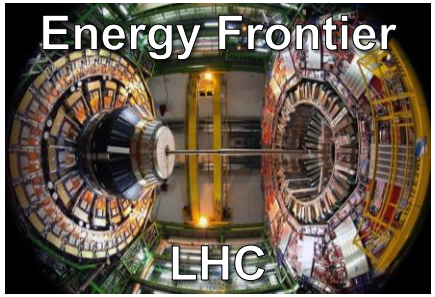
Understanding how the universe works at its most fundamental level

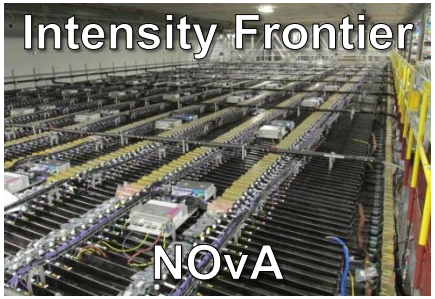
- The FY 2017 HEP budget reflects the way the P5 plan has evolved as the U.S. and international community have adopted and responded to it

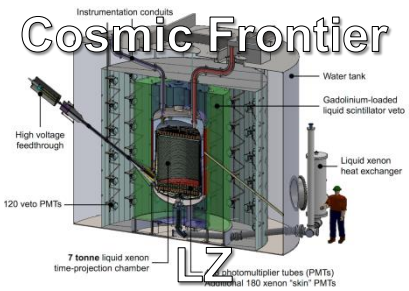
- Energy Frontier: Continue active engagement in highly successful LHC program
  - Initial LHC detector upgrade project funding ends in FY 2017
  - Scope being determined for high luminosity(HL)- LHC, P5's highest priority near-term project; CD-0 in 2016
  - The U.S. will continue to play a leadership role in LHC discoveries by remaining actively engaged in LHC data analysis of world's highest energy particle collider data, at 13 TeV

- Intensity Frontier: Solidify international partnerships for U.S.-hosted LBNF/DUNE
  - Rapid progress on LBNF/DUNE has attracted attention from interested international partners, and FY 2017 investments in site preparation and cavern excavation aim to solidify formal agreements
  - Fermilab will continue improvements to accelerator complex while serving high-intensity neutrino beams to short-and long-baseline experiments enabling full utilization of the FNAL facilities

- Cosmic Frontier: Advance our understanding of dark matter and dark energy
  - Fabrication funding ramp up in FY 17 supports key P5 recommended Cosmic Frontier projects to study dark matter and dark energy: LSSTcam, DESI, SuperCDMS-SNOLab, and LZ





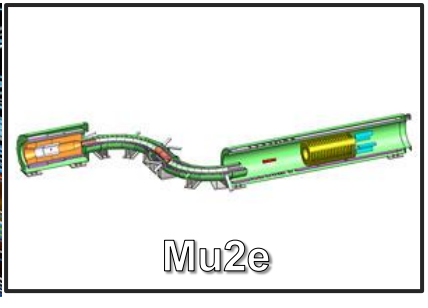


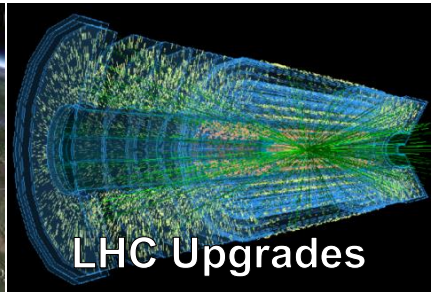
	Energy Frontier	Intensity Frontier	Cosmic Frontier
Higgs Boson	●		
Neutrino Mass		●	●
Dark Matter	●	●	●
Cosmic Acceleration			●
Explore the Unknown	●	●	●

High Energy Physics

The technology and construction needed to pursue to physics

- Construction & project support increases to implement the P5 strategy:
  - LBNF/DUNE aims to solidify partnerships with FY 2017 investments in site preparation and excavation of caverns for the neutrino detectors and cryogenic infrastructure
  - LHC ATLAS and CMS Detector Upgrade projects continue fabrication; HL-LHC upgrades begin
  - Muon g-2 completes project funding profile and will begin receiving beam at Fermilab
  - Dark energy: LSSTcam and DESI fabrication support increase according to planned profiles
  - Dark matter: LZ will continue fabrication as SuperCDMS-SNOLab proceeds to final design
  - Construction continues for the Muon to Electron Conversion Experiment (Mu2e)
  - FACET-II support begins, in order to create a new facility that will enable accelerator R&D aimed at dramatically improved capability and cost-effectiveness in future high-energy colliders
- Accelerator Stewardship
  - AS works to make particle accelerator technology widely available to science and industry by supporting use-inspired basic research in accelerator science and technology
  - FY17 Request supports research activities at laboratories, universities, and in industry for technology R&D areas such as laser, ion-beam therapy, and accelerator technology for energy and environmental applications
  - FY17 Request supports Brookhaven Accelerator Test Facility (ATF) operations and the continuation of the Accelerator Stewardship Test Facility Pilot Program





HEP FY 2017 Budget Request to Congress

(Dollars in thousands)

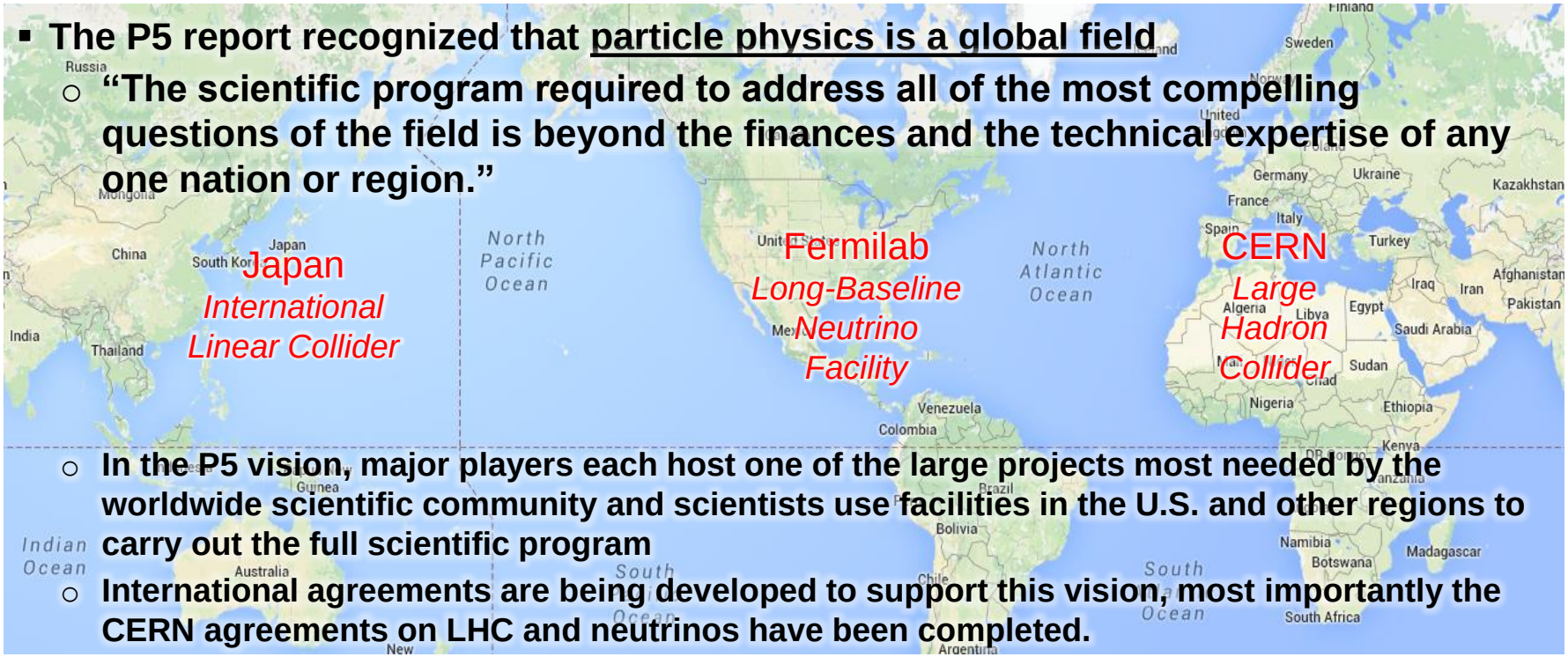
	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Energy Frontier Experimental Physics						
Research	78,782	84,387	77,270	76,811	-459	-0.6%
Facility Operations and Experimental Support	53,802	53,670	54,453	55,220	+767	+1.4%
LHC CMS Detector Upgrades (MIE)	7,500	5,162	9,500	7,967	-1,533	-16.1%
LHC ATLAS Detector Upgrades (MIE)	7,500	2,821	9,500	8,500	-1,000	-10.5%
ATLAS HI-Lum Upgrades (MIE)	…	…	…	1,250	+1,250	…
CMS HI-Lum Upgrades (MIE)	…	…	…	1,250	+1,250	…
Total, Energy Frontier Experimental Physics	**147,584**	**146,040**	**150,723**	**150,998**	**+275**	**+0.2%**
Intensity Frontier Experimental Physics						
Research	55,181	54,122	56,104	56,509	+405	+0.7%
Facility Operations and Experimental Support	165,073	158,658	151,317	153,066	+1,749	+1.2%
Belle-II (MIE)	970	970	…	…	…	…
Muon g-2 Experiment (MIE)	13,000	13,000	10,200	6,349	-3,851	-37.8%
Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment (Line Item OPC)	10,000	10,000	…	…	…	…
Proton Improvement Plan II (Line Item OPC)	…	…	18,015	15,220	-2,795	-15.5%
Future Project R&D	20,000	23,000	7,485	3,000	-4,485	-59.9%
Total, Intensity Frontier Experimental Physics	**264,224**	**259,750**	**243,121**	**234,144**	**-8,977**	**-3.7%**
Cosmic Frontier Experimental Physics						
Research	49,310	48,777	49,910	49,934	+24	+0.0%
Facility Operations and Experimental Support	11,832	11,327	13,837	9,935	-3,902	-28.2%
Large Synoptic Survey Telescope Camera (LSSTcam) (MIE)	35,000	35,000	40,800	45,000	+4,200	+10.3%
LUX-ZEPLIN (LZ) (MIE)	2,800	3,050	10,500	10,500	…	…
SuperCDMS-SNOLab (MIE)	2,000	2,250	3,000	4,000	+1,000	+33.3%
Dark Energy Spectroscopic Instrument (DESI) (MIE)	3,603	3,878	10,300	10,000	-300	-2.9%
Other Projects	2,225	1,025	2,035	…	-2,035	-100.0%
Future Project R&D	100	1,200	200	700	+500	+250.0%
Total, Cosmic Frontier Experimental Physics	**106,870**	**106,507**	**130,582**	**130,069**	**-513**	-0.4%

HEP FY 2017 Budget Request to Congress
(Dollars in thousands)

	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Theoretical and Computational Physics						
Research	58,274	60,848	57,083	57,656	+573	+1.0%
Projects (Other)	1,000	1,000	2,000	2,000	…	…
Total, Theoretical and Computational Physics	**59,274**	**61,848**	**59,083**	**59,656**	**+573**	**+1.0%**
Advanced Technology R&D						
Research	89,936	88,217	83,644	83,360	-284	-0.3%
Facility Operations and Experimental Support	30,318	35,870	29,750	26,925	-2,825	-9.5%
FACET II (MIE)	…	…	2,100	8,000	+5,900	+281.0%
Total, Advanced Technology R&D	**120,254**	**124,087**	**115,494**	**118,285**	**+2,791**	**+2.4%**
Accelerator Stewardship						
Research	5,900	4,891	3,378	6,853	+3,475	+102.9%
Facility Operations and Experimental Support	4,100	5,109	5,622	6,891	+1,269	+22.6%
Total, Accelerator Stewardship	**10,000**	**10,000**	**9,000**	**13,744**	**+4,744**	**+52.7%**
SBIR/STTR	**20,794**	**…**	**20,897**	**22,580**	**+1,683**	**+8.1%**
Subtotal, HEP	**729,000**	**708,232**	**728,900**	**729,476**	**+576**	**+0.1%**
Construction						
11-SC-40 Long Baseline Neutrino Facility/Deep Underground Neutrino Experiment, FNAL	12,000	12,000	26,000	45,021	+19,021	+73.2%
11-SC-41 Muon to Electron Conversion Experiment, FNAL	25,000	25,000	40,100	43,500	+3,400	+8.5%
Total, Construction	**37,000**	**37,000**	**66,100**	**88,521**	**+22,421**	**+33.9%**
Total, High Energy Physics	**766,000**	**745,232**	**795,000**	**817,997**	**+22,997**	**+2.9%**

High Energy Physics

Understanding how the universe works at its most fundamental level

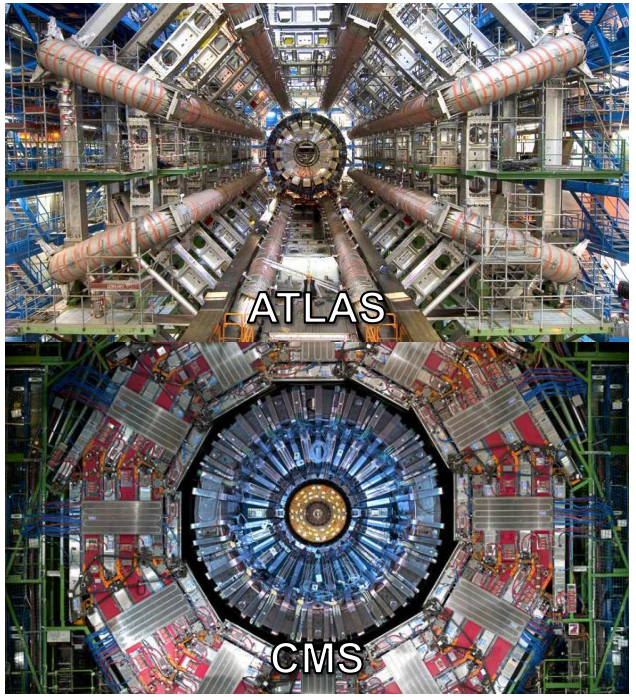


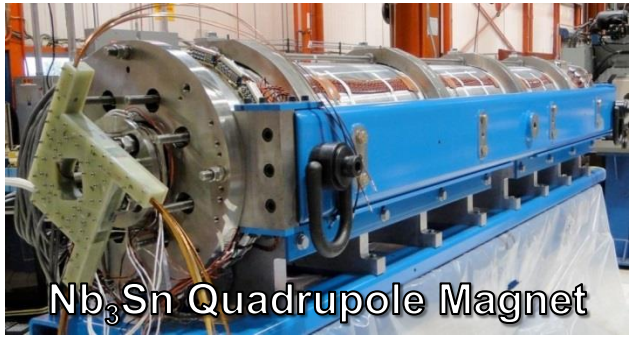
- **The P5 report recognized that particle physics is a global field**
  - **"The scientific program required to address all of the most compelling questions of the field is beyond the finances and the technical expertise of any one nation or region."**
  - **In the P5 vision, major players each host one of the large projects most needed by the worldwide scientific community and scientists use facilities in the U.S. and other regions to carry out the full scientific program**
  - **International agreements are being developed to support this vision, most importantly the CERN agreements on LHC and neutrinos have been completed.**

- The P5 report recommends a **limited, prioritized and time-ordered list of experiments** to optimally address the science drivers
  - **Increase investments in a portfolio of projects** at the small, medium and large scales while **maintaining balanced facility operations and research** to produce results continuously throughout a 20-year timeframe
  - Major elements of the P5 plan include High-Luminosity LHC (HL-LHC), LBNF/DUNE, LSST, and a healthy cosmic program to study dark matter and dark energy

LHC: The Central Component of the Energy Frontier Program

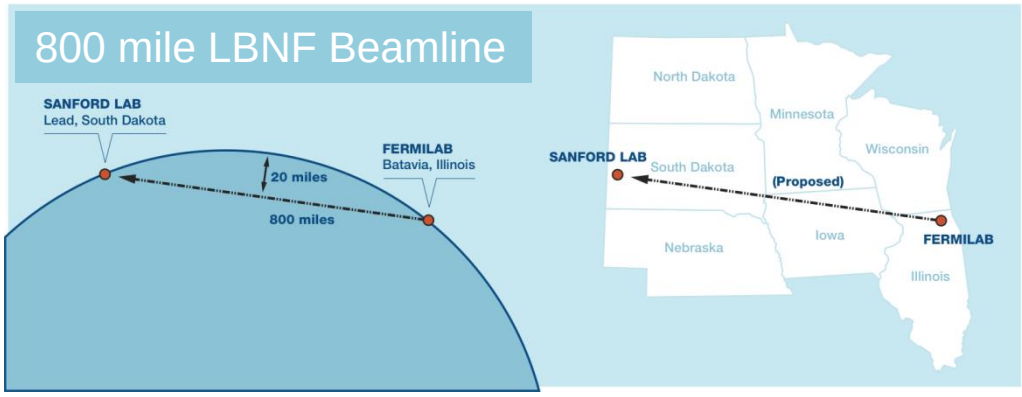
- U.S. investments enable leading roles in LHC collaborations
- P5 report identified LHC upgrades as the highest priority near-term large project
  - HL-LHC upgrades will extend discovery potential by increasing luminosity a factor of 10
- U.S. leadership in superconducting magnet technology in general, and with Nb_3Sn in particular, is essential to the success of the HL-LHC project
  - LHC Accelerator Research Program (LARP) uses this expertise to serve HEP community needs
- U.S. laboratories and institutions will develop and build major subsystems for the upgraded ATLAS and CMS detectors
  - Detector expertise and support provides foundation for continued U.S. leadership in HL-LHC scientific research program

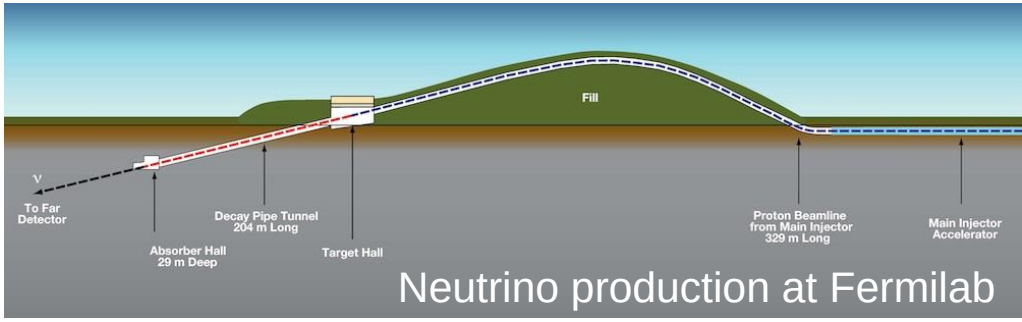


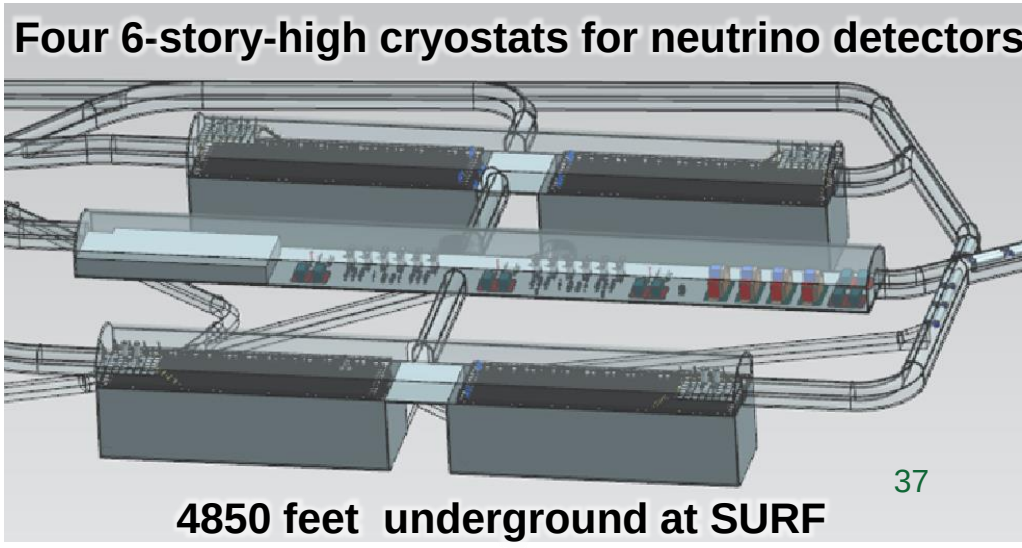


Long Baseline Neutrino Facility

- U.S.-hosted, world-class Long Baseline Neutrino Facility identified by P5 as “the highest-priority large project in its timeframe.”
- Community, led by Fermilab, has made significant progress in past year:
  - Established international governance based on successful LHC model
  - Reformulated conceptual design based on P5 recommendations and input from established and potential international partners
- Current design features:
  - New neutrino beam at Fermilab with over 1 megawatt initial beam power
  - 800 mile distant large Liquid Argon Time Projection Chamber (LArTPC) detector deep underground at Homestake mine in Lead, SD







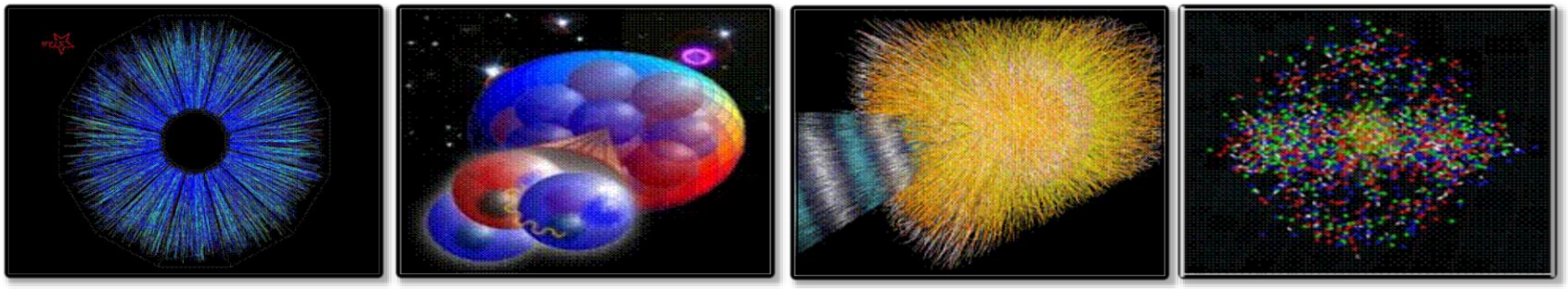
Progress on Developing LBNF/DUNE

- The international effort on LBNF/DUNE made impressive progress in 2015.
- An collaboration of 750 physicists from 26 countries has formed.
- The experimental design has been enhanced to deliver more physics on a faster time scale.
- DOE has an signed agreement with CERN to cooperate on LBNF/DUNE, and CERN has allocated significant support in their 2015 financial plan.
- This new design was evaluated by an independent project review and was found to meet mission need. CD-1 for this new design was approved by DOE in November 2015.
  - The DOE LBNF/DUNE cost range at CD-1 is $1,260 to $1,860 million with foreign in kind contributions adding another ~30%.
- Preparation of the site has begun to allow excavation to start in late FY 17.
- Another independent project review evaluated the readiness of the project to begin excavating detector halls at the Homestake Mine in South Dakota. The review panel found the project ready to proceed with underground excavation.

Nuclear Physics

Discovering, exploring, and understanding all forms of nuclear matter

- Funding for **research** increases to advance activities across the program, including R&D to develop new approaches for isotopes not currently available in sufficient quantities.
- A **graduate traineeship** is initiated in radiochemistry and nuclear chemistry with an emphasis in isotope production ($1M).
- Operations at **RHIC** increase to explore the properties of the quark gluon plasma first discovered there and to enable studies of spin physics.
- The **12 GeV CEBAF Upgrade** is completed in FY 2017 and the scientific program is initiated promising new discoveries and an improved understanding of quark confinement.
- Construction continues on the **Facility for Rare Isotope Beams.** The **Gamma-Ray Energy Tracking Array (GRETA)** MIE is initiated to exploit the scientific potential of FRIB.
- Fabrication begins for a **Stable Isotope Production Facility (SIPF)** to produce enriched stable isotopes, a capability not available in the U.S. for almost 20 years.



NP FY 2017 Budget Request to Congress

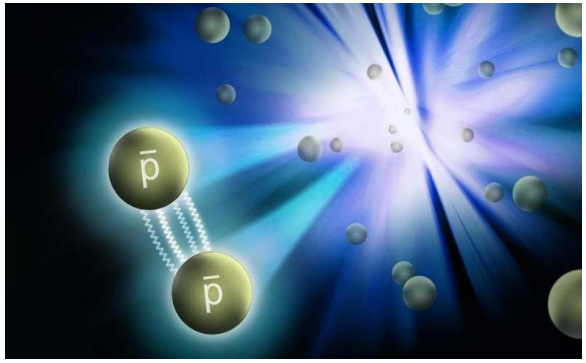
(Dollars in thousands)

	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Medium Energy Nuclear Physics						
Research	35,646	35,429	37,802	40,017	+2,215	+5.9%
Operations (TJNAF)	97,050	97,050	98,670	104,139	+5,469	+5.5%
SBIR/STTR and Other	18,196	1,863	19,321	19,643	+322	+1.7%
Total, Medium Energy Nuclear Physics	**150,892**	**134,342**	**155,793**	**163,799**	**+8,006**	**+5.1%**
Heavy Ion Nuclear Physics						
Research	33,894	33,013	35,822	36,431	+609	+1.7%
Operations (RHIC)	166,072	166,072	172,088	179,700	+7,612	+4.4%
Total, Heavy Ion Nuclear Physics	**199,966**	**199,085**	**207,910**	**216,131**	**+8,221**	**+4.0%**
Low Energy Nuclear Physics						
Research	48,377	50,764	51,383	53,894	+2,511	+4.9%
Gamma-Ray Energy Tracking Array (GRETA) (MIE)	…	…	…	500	+500	…
Operations	26,819	27,029	27,402	25,499	-1,903	-6.9%
Total, Low Energy Nuclear Physics	**75,196**	**77,793**	**78,785**	**79,893**	**+1,108**	**+1.4%**
Nuclear Theory						
Theory Research	35,715	35,620	38,033	38,583	+550	+1.4%
Nuclear Data Activities	7,381	7,554	7,742	7,882	+140	+1.8%
Total, Nuclear Theory	**43,096**	**43,174**	**45,775**	**46,465**	**+690**	**+1.5%**
Isotope Development and Production for Research and Applications						
Research	4,815	4,815	6,033	10,344	+4,311	+71.5%
Operations	15,035	15,035	15,304	16,526	+1,222	+8.0%
Stable Isotope Production Facility (SIPF) (MIE)	…	…	…	2,500	+2,500	…
Total, Isotope Production and Applications	**19,850**	**19,850**	**21,337**	**29,370**	**+8,033**	**+37.6%**
Subtotal, Nuclear Physics	**489,000**	**474,244**	**509,600**	**535,658**	**+26,058**	**+5.1%**
Construction						
14-SC-50 Facility for Rare Isotope Beams, MSU	90,000	90,000	100,000	100,000	…	…
06-SC-01 12 GeV CEBAF Upgrade, TJNAF	16,500	16,500	7,500	…	-7,500	-100.0%
Total, Construction	**106,500**	**106,500**	**107,500**	**100,000**	**-7,500**	**-7.0%**
Total, Nuclear Physics	**595,500**	**580,744**	**617,100**	**635,658**	**+18,558**	**+3.0%**

Relativistic Heavy Ion Collider

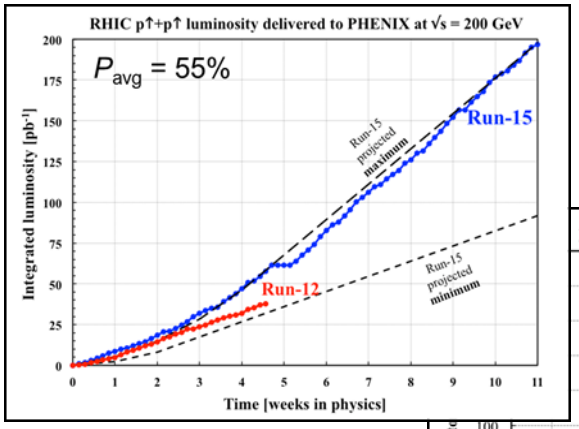
- **RHIC operates for 24 weeks, 4 more than FY 2016.**
- **The FY 2017 request enables incisive tests of our understanding of QCD and exploration of new phenomena in quark gluon plasma formation.**

(*Nature,*11/4/15)
Physicists measure the force that makes anti-matter stick together



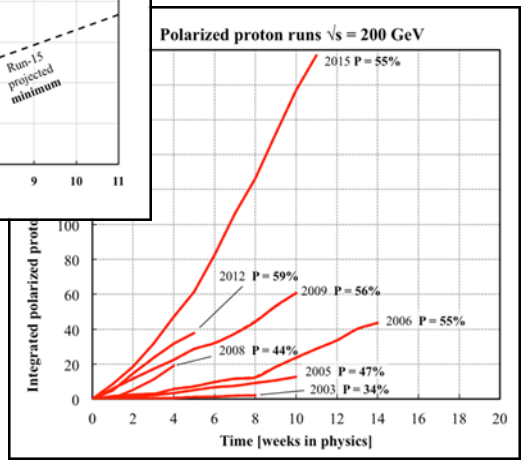
Findings could offer insight into the possible existence of larger chunks of antimatter and may also help scientists explore why the universe today consists mainly of ordinary matter with virtually no antimatter to be found.

Record RHIC Luminosity Achieved … Again!



Run-15 integrated luminosity at √s = 200 GeV exceeds sum of all previous runs

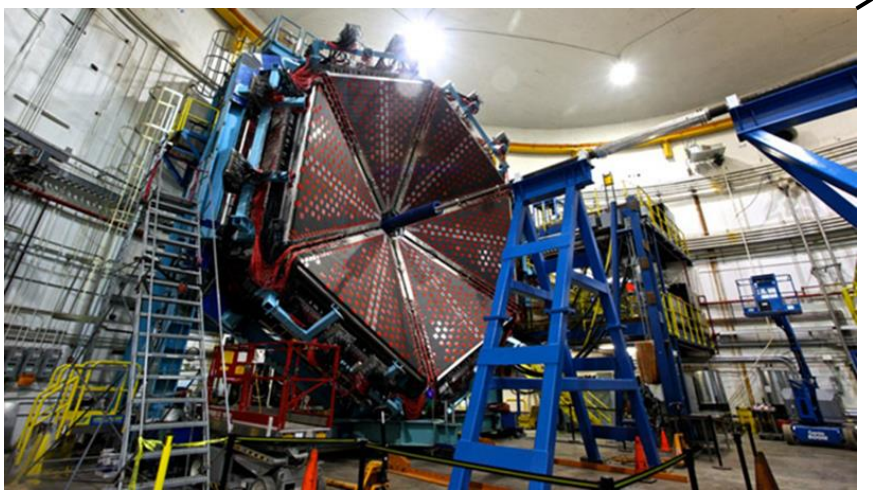
2015



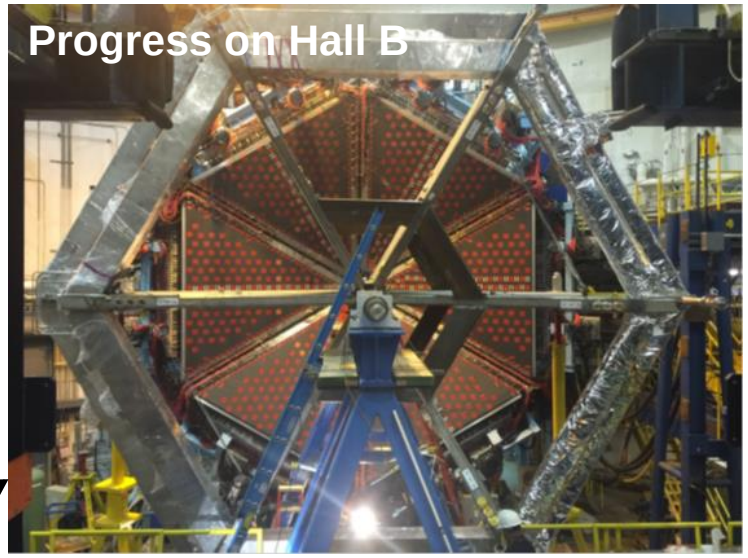
Continuous Electron Beam Accelerator Facility

12 GeV CEBAF Upgrade Project:

- Major milestones planned in FY 2017 include completing the beam commissioning in Halls B & C and the entire 12 GeV CEBAF Upgrade Project (CD-4B).
- Project funding is provided for commissioning the upgraded experimental Halls B and C as the project is completed and transitioned to the 12 GeV CEBAF experimental program.



CEBAF operates for 27 weeks in FY 2017



With the completion of the 12 GeV CEBAF Upgrade, researchers will address:

- The search for exotic new quark-anti-quark particles to advance our understanding of the strong force.
- Evidence of new physics from sensitive searches for violations of nature's fundamental symmetries.
- A microscopic understanding of the internal structure of the proton, including the origin of its spin, and how this structure is modified when the proton is inside a nucleus.

Facility for Rare Isotope Beams

FRIB will increase the number of isotopes with known properties from ~2,000 observed over the last century to ~5,000 and will provide world-leading capabilities for research on:

Nuclear Structure

- The limits of existence for nuclei
- Nuclei that have neutron skins
- Synthesis of super heavy elements

Nuclear Astrophysics

- The origin of the heavy elements and explosive nucleo-synthesis
- Composition of neutron star crusts

Fundamental Symmetries

- Tests of fundamental symmetries, Atomic EDMs, Weak Charge

This research will provide the basis for a model of nuclei and how they interact.

FRIB civil construction is 10 weeks ahead of schedule

The FY2017 Request supports:

- Completing key conventional construction such as the target high bay, linac support area, and the cryoplant area.
- Enabling start of work on the cryogenics plant and distribution system which are on the project's critical path.
- Continuing major procurements, fabrication, and assembly efforts of technical systems such as the linac front end, cryomodules, and experimental systems.

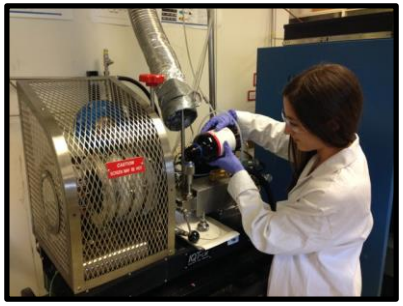
Stable Isotope Production Facility (SIPF)

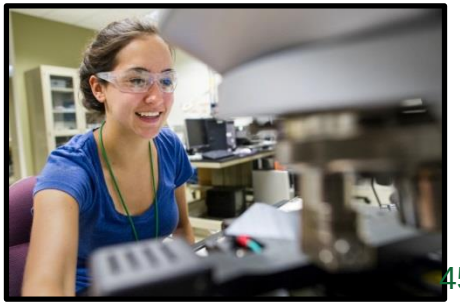
- The Request initiates the SIPF MIE, which restores domestic capability lacking since 1998.
  - Renewed enrichment capability will benefit nuclear and physical sciences, industrial manufacturing, homeland security, and medicine.
  - Nurtures U.S. expertise in centrifuge technology and isotope enrichment, useful for a variety of peaceful-use activities.
  - Addresses U.S. demands for high priority isotopes needed for neutrinoless double beta decay, dark matter experiments, target material for Mo-99 production, and more.
  - Removes U.S. foreign dependence of stable isotope enrichment
  - Responds to Nuclear Science Advisory Committee – Isotopes (NSACI)
    - 2009 Recommendation: “Construct and operate an electromagnetic isotope separator facility for stable and long-lived radioactive isotopes.”
    - 2015 Long Range Plan: “We recommend completion and the establishment of effective, full intensity operations of the stable isotope separation capability at ORNL.”

Workforce Development for Teachers and Scientists

Ensuring a pipeline of STEM workers to support the DOE mission

- At DOE labs and facilities, WDTS will support more than1,000 students and faculty
  - 845 Science Undergraduate Laboratory Interns (SULI) placed at one of 17 DOE labs or facilities
  - 105 Community College Interns (CCI)
  - 100 graduate students engaged in Ph.D. thesis research for 3-12 months at a DOE laboratory
  - 70 faculty and 40 students in the Visiting Faculty Program (VFP)
- Support for the National Science Bowl
  - More than 20,000 students, coaches, and volunteers participate in the regional and final competitions.
  - In FY 2016, there are 120 regional events, involving 13,500 students from all fifty states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. The NSB has had more than 250,000 total participants.
- Support for 6 Albert Einstein Distinguished Educator Fellows
- Support for on-line business systems modernization
  - On-line systems to manage applications and review; data collection; and evaluation for all programs.
- Support for program evaluation and assessment
  - Supports work to assess whether WDTS programs meet established goals through the use of collection and analysis of data and other materials, including pre- and post-participation questionnaires, participant deliverables, participant notable outcomes, and longitudinal participant tracking.





WDTS FY 2017 Budget Request to Congress

(Dollars in thousands)

	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Activities at the DOE Laboratories						
Science Undergraduate Laboratory Internships	8,300	8,300	8,300	9,300	+1,000	+12.0%
Community College Internships	1,000	1,000	1,000	1,250	+250	+25.0%
Graduate Student Research Program	2,500	2,500	2,500	2,575	+75	+3.0%
Visiting Faculty Program	1,700	1,700	1,700	1,800	+100	+5.9%
Total, Activities at the DOE Laboratories	**13,500**	**13,500**	**13,500**	**14,925**	**+1,425**	**+10.6%**
Albert Einstein Distinguished Educator Fellowship	1,200	1,200	1,200	1,200	...	...
National Science Bowl®	2,900	2,930	2,900	3,000	+100	+3.4%
Technology Development & On-Line Application	750	750	750	675	-75	-10.0%
Evaluation Studies	600	600	600	600	...	...
Outreach	500	470	500	525	+25	+5.0%
Laboratory Equipment Donation Program	50	50	50	...	-50	-100.0%
Total, Workforce Development for Teachers and Scientists	**19,500**	**19,500**	**19,500**	**20,925**	**+1,425**	**+7.3%**

Science Laboratories Infrastructure (SLI)

Providing critical general-purpose infrastructure that enables Laboratory core capabilities

Two New Construction Projects

Artist's rendering of the new facility adjacent to Wilson Hall

Existing RHIC/ATLAS Computing Facility

Integrated Engineering Research Center, Fermi National Accelerator Laboratory

- Co-locates engineering and research staff from poor-quality space across the site to a new facility on the central campus.
- Enables a world-leading neutrino program by increasing interdisciplinary collaboration among technical and scientific staff who design and execute experiments.
- Positions Fermilab to attract a new generation of the world's leading scientific users, drawing from CERN and other international research organizations.

Core Facility Revitalization, Brookhaven National Laboratory

- Provides computation and data storage capabilities to support the Relativistic Heavy Ion Collider and the ATLAS programs.
- Replaces existing infrastructure that is projected to rapidly degrade over the next several years, just as the data volume generated by RHIC and ATLAS is expected to increase significantly.
- Will help ensure BNL can continue to meet its data storage and computation needs.

SLI FY 2017 Budget Request to Congress
(Dollars in thousands)

	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Infrastructure Support						
Payment in Lieu of Taxes	1,713	1,713	1,713	1,764	+51	+3.0%
Oak Ridge Landlord	5,777	5,777	6,177	6,182	+5	+0.1%
Facilities & Infrastructure						
Infrastructure/GPP	...	...	22,400	29,000	+6,600	+29.5%
All Other	6,100	6,100	2,400	3,603	+1,203	+50.1%
Total, Facilities & Infrastructure	6,100	6,100	24,800	32,603	+7,803	+31.5%
Oak Ridge Nuclear Operations	...	...	12,000	26,000	+14,000	+116.7%
Total, Infrastructure Support	**13,590**	**13,590**	**44,690**	**66,549**	**+21,859**	**+48.9%**
Construction						
Integrated Engineering Research Center at FNAL (17-SC-71)	...	...	...	2,500	+2,500	...
Core Facility Revitalization at BNL (17-SC-73)	...	...	...	1,800	+1,800	...
Infrastructure and Operational Improvements at PPPL (15-SC-75)	25,000	25,000	...	...	...	...
Materials Design Laboratory at ANL (15-SC-76)	7,000	7,000	23,910	19,590	-4,320	-18.1%
Photon Sciences Laboratory Building at SLAC (15-SC-77)	10,000	10,000	25,000	20,000	-5,000	-20.0%
Integrative Genomics Building at LBNL (15-SC-78)	12,090	12,090	20,000	19,561	-439	-2.2%
Science and User Support Building at SLAC (12-SC-70)	11,920	11,920	...	...	...	...
Total, Construction	**66,010**	**66,010**	**68,910**	**63,451**	**-5,459**	**-7.9%**
Total, Science Laboratories Infrastructure	**79,600**	**79,600**	**113,600**	**130,000**	**+16,400**	**+14.4%**

Safeguards and Security

Supporting protection against unauthorized access, theft, or destruction of assets

- Maintains adequate security for the special nuclear material housed in Building 3019 at the Oak Ridge National Laboratory.
- Ensures the Cyber Security program is properly funded to detect, mitigate, and recover from cyber security intrusions and attacks against protected information.
- Supports the CyberOne strategy--DOE's solution for managing enterprise-wide cyber-security for incident response and identity management to mitigate the risk of intrusion.
- Sustains operation levels and ensures appropriate security measures are in place to support SC mission requirements and protect critical assets within SC laboratories.

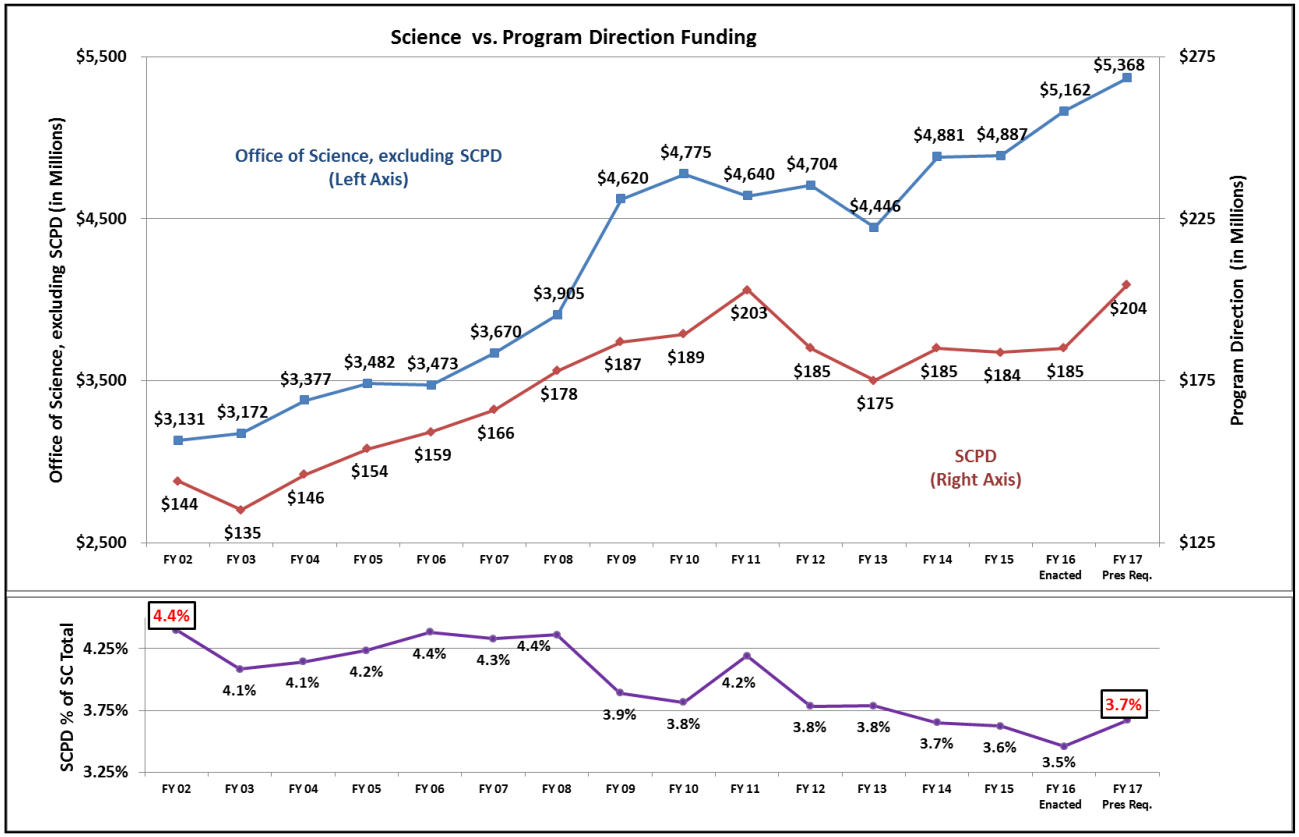
S&S FY 2017 Budget Request to Congress

(Dollars in thousands)

	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Protective Forces	38,095	37,767	38,805	39,638	+833	+2.1%
Security Systems	12,601	11,314	12,019	10,357	-1,662	-13.8%
Information Security	4,252	4,268	4,416	4,467	+51	+1.2%
Cyber Security	24,118	25,781	33,156	33,236	+80	+0.2%
Personnel Security	5,267	5,335	5,412	6,086	+674	+12.5%
Material Control & Accountability	2,223	2,256	2,454	2,458	+4	+0.2%
Program Management	6,444	6,279	6,738	6,758	+20	+0.3%
Total, Safeguards and Security	**93,000**	**93,000**	**103,000**	**103,000**	...	...

Program Direction

The FY 2017 PD budget supports 930 FTEs



Support for:

- Management of the Office of Science programs, facilities, and projects;
- Business operations associated with portfolio management;
- Federal travel for scientific program and laboratory operations oversight;
- A consolidated source for most of the Working Capital Fund;
- President's Council of Advisors on Science and Technology (PCAST);
- Office of the Under Secretary for Science and Energy (S-4).

During the past 15 years, the ratio of the Program Direction budget to the SC appropriation has decreased from 4.4% to about 3.7% -- now one of the lowest ratios in DOE. Further, the field staffing levels (FTEs) have decreased by 12% since FY11. The decreases have been accomplished through management initiatives implemented across the SC organization. Some of these initiatives include:

- Sharing of resources between the Oak Ridge and Chicago locations of the Integrated Service Center.
- Increase in workforce planning and analysis efforts (e.g. Internal reviews, field-wide workforce planning and prioritization efforts).
- Consolidation of IT data centers and support service contracts as part of Science IT Modernization Plan.

PD FY 2017 Budget Request to Congress

(Dollars in thousands)

	FY 2015 Enacted Approp.	FY 2015 Current Approp.	FY 2016 Enacted Approp.	FY 2017 President's Request	FY 2017 President's Req. vs. FY 2016 Enacted Approp.	
Program Direction						
Salaries and Benefits	137,055	135,360	133,880	141,850	+7,970	+6.0%
Travel	3,399	3,637	3,738	4,150	+412	+11.0%
Support Services	19,302	21,338	20,515	20,000	-515	-2.5%
Other Related Expenses	23,944	23,365	26,867	38,481	+11,614	+43.2%
Total, Program Direction	**183,700**	**183,700**	**185,000**	**204,481**	**+19,481**	**+10.5%**
Full Time Equivalents	***940***	***902***	***905***	***930***	***+25***	***+2.8%***